# DOCUMENT RESUME

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| INSTITUTION | Air Force Training Command, Sheppard AFB, Tex. |
| PUB DATE | 83 |
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| IDENTIFIERS | Air Force; Military Curriculum Materials |

ABSTRACT

This instructional package is intended for use in training Air Force personnel enrolled in a program for apprentice heating systems specialists. Training includes instruction in fundamentals and pipefitting; basic electricity; controls, troubleshooting, and oil burners; solid and gas fuel burners and warm air distribution systems; hot water heating systems; central plant and high-temperature heating systems; boiler maintenance and steam distribution systems; and boiler water treatment and corrosion control. The package contains a set of lesson plans, eight study guides, and eight workbooks. Included in each lesson plan are a course content outline, lists of pertinent student instructional materials, approximate times to complete each phase of the course, suggested teaching methods, and instructional guidance. The study guides consist of series of instructional units, each of which contains an objective, an introduction, instructional text, and questions. Numerous figures and diagrams illustrate the text. The accompanying workbooks include objectives, list of needed equipment, instructions for performing various tasks, and written exercises. (MN)

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# HEATING SYSTEMS SPECIALIST

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SHEPPARD TECHNICAL TRAINING COMMAND

(PDS Code 4CC)

# PLAN OF INSTRUCTION
(Technical Training)

## HEATING SYSTEMS SPECIALIST

SHEPPARD TECHNICAL TRAINING CENTER
3 January 1984-Effective 16 January 1984 with Class 840116
Changed 11 May 1984-Effective 22 May 1984 with Class 840522
Changed 27 August 1984-Effective 14 September 1984 with Class 840914
Changed 20 September 1985-Effective 3 October 1984 with Class 851003

## LIST OF CURRENT PAGES

This POI consists of 111 current pages as follows.

| PAGE NO. | ISSUE | PAGE NO. | ISSUE |
|---|---|---|---|
| *Title . . . . . . | 20 September 1985 | 53 thru 54 . . . . . . . . | Original |
| *A . . . . . . . . . | 20 September 1985 | *55 . . . . . . . . . . . . | 20 September 1985 |
| i. . . . . . . . . . | Original | 56 thru 65 . . . . . . . . | Original |
| ii . . . . . . . . . | 11 May 1984 | 66 . . . . . . . . . . . . | Blank |
| iii thru iv. . . . | 27 August 1984 | 67 thru 69 . . . . . . . . | Original |
| *v . . . . . . . . . | 20 September 1985 | 70 . . . . . . . . . . . . | Blank |
| 1 thru 5 . . . . . | Original | 71 thru 79 . . . . . . . . | Original |
| 6. . . . . . . . . . | Blank | 80 . . . . . . . . . . . . | Blank |
| 7 thru 15. . . . . | Original | 81 . . . . . . . . . . . . | Original |
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| 17 thru 19 . . . . | Original | 83 thru 85 . . . . . . . . | Original |
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| 25 . . . . . . . . . | Original | 95 thru 97 . . . . . . . . | Original |
| 26 . . . . . . . . . | Blank | 98 . . . . . . . . . . . . | Blank |
| 27 thru 31 . . . . | Original | 99 thru 101. . . . . . . . | Original |
| 32 . . . . . . . . . | Blank | 102. . . . . . . . . . . . | Blank |
| 33 thru 51 . . . . | Original | 103 thru 104 . . . . . . . | Original |
| 52 . . . . . . . . . | Blank | | |

## CHANGE NOTICE INSTRUCTIONS

Effective 3 October 1985, POI J3ABR54532 001, 3 January 1984, is changed as follows:

1. Make write-in changes identified on Page v.

2. Remove replaced or deleted pages and insert changed and new pages according to the above listing.

3. The asterisk (*) above indicates that a page is a replacement or addition or has been deleted by this change notice.

James M. Pirkle

JAMES M. PIRKLE, Major, USAF
Executive Officer, 3770 Tech Tng Gp

DISTRIBUTION: ATC/TTQJ-1; AU/LSE-1; CCAF/AY-1; USAFOMC/OMY-1; Sheppard: XPMT-1; TTGIM-50; TTGXD-2; TTGXR-1; TTS-1

DEPARTMENT OF THE AIR FORCE
3770 Technical Training Group (ATC)
Sheppard Air Force Base, Texas 76311

PLAN OF INSTRUCTION J3ABR54532 001
(PDS Code 4CC)
3 January 1984

## FOREWORD

1. PURPOSE. This publication is the plan of instruction (POI) when the pages listed on page A are bound into a single volume. The POI contains the qualitative requirements for Course J3ABR54532 001, Heating Systems Specialist, in terms of criterion objectives for each unit of instruction and shows time, training standard correlation, and support materials and guidance. When separated into units of instruction, it becomes the lesson plan/Part 1. This POI was developed according to AFR 50-8, Instructional Systems Development (ISD), and ATCR 52-6, Curricula Documentation.

2. COURSE DESIGN/DESCRIPTION. The instructional design for this course is Group/Lock/Step. This course trains selected Air Force maintenance personnel to perform duties described in AFR 39-1 for Heating Systems Specialist AFSC 54532. Training includes the use of AF publications and forms, and commercial manuals related to the identification, location, function, installation, operation, servicing, repair and maintenance of heating equipment, plants and systems. The course also includes boiler water testing and treatment and solar heating.

3. REFERENCES. This POI is based on Specialty Training Standard 545X2, December 1981, Change 1, November 1983, and Course Chart J3ABR54532 001, 1 December 1983.

FOR THE COMMANDER

DAVID K. JACKSON, Colonel, USAF
Commander, 3770 Technical Training Group

Supersedes Plan of Instruction J3ABR54532 001, 5 July 1983.
OPR: 3770 Technical Training Group
DISTRIBUTION: Listed on Page A

WRITE-IN CHANGES EFFECTIVE DATE: 22 May 84

| BLOCK | PAGE | ACTION |
|---|---|---|
| I | 4 | Change objective 2i to read "Given AFM 85-12 and instructions, locate information on maintenance and inspection of heating equipment with instructor assistance." |
| | | Underline STS element 4c. |
| I | 9 | On objective 4c, delete STS element 4c. |
| I | 11 | Change objective 41 to read "Given information, blueprints, drawings and symbols, interpret blueprints and drawings by answering 70% of questions correctly. |
| III | 33 | Change objective 2a to read "Given step-by-step procedures, troubleshoot electrical controls on a warm air furnace trainer with instructor assistance." |
| | | Delete STS element 9a(8) on objective 2a. |
| | | Delete teaching steps on objective 2a. |
| IV | 49 | On objective 4b, delete "10 out of 12" and add "80% of the" |
| V | 61 | Change objective 4a to read "Given procedures, remove a boiler from service, drain, flush and fill boiler and check boiler for proper operation, with instructor assistance." |
| V | 63 | Hours for unit 5 should be 12.5/3 |
| VI | 68 | On objective 1h, add STS element 9a(8). |

POI J3ABR54532 001 Changed 27 August 1984

WRITE-IN CHANGES

Effective Date: 14 September 1984

| BLOCK | PAGE | ACTION |
|---|---|---|
| I | 3 | Objective 2a, change standard to read "by correctly answering 2 out of 3 questions." |
| I | 3 | Objective 2b, change standard to read "by correctly answering 6 out of 8 questions. |
| I | 3 | Objective 2c, change standard to read "by correctly answering 4 out of 6 questions." |
| I | 3 | Objective 2d, change standard to read "by correctly answering 6 out of 9 questions." |
| I | 4 | Objective 2h, change standard to read "by correctly answering 4 out of 6 questions." |
| I | 5 | Under Student Instructional Materials, add AFM 85-12, Vols I and II.(See Instructor Reference Materials) |
| I | 10 | Objective 4f, change standard to read "by correctly answering 6 out of 8 questions." |
| I | 10 | Objective 4h, change standard to read "by correctly answering 6 out of 8 questions. |
| I | 10 | Objective 4j, change standard to read "by correctly answering 80% of the questions." |
| I | 11 | Objective 41, change standard to read "by correctly answering 5 out of 7 questions." |
| I | 13 | Objective 5b, change standard to read "by correctly answering 2 out of 3 questions." |
| I | 13 | Objective 5c, change standard to read "by correctly answering 2 out of 3 questions." |
| II | 25 | Objective 5c, change standard to read "by correctly identifying the amperage characteristics of 3 out of 4 electrical devices." |
| III | 33 | Objective 2a, change time in column 2 to (2.5/1). |
| III | 33 | Objective 2b, change time in column 2 to (2.5/1). |
| IV | 53 | Objective 5c, change standard to read "by correctly answering 3 out of 4 questions." |
| IV | 53 | Objective 5e, change standard to read "by correctly answering 6 out of 8 questions." |

| BLOCK | PAGE | ACTION |
|---|---|---|
| V | 57 | Objective 2b, change standard to read "by correctly answering 2 out of 3 questions." |
| VI | 67 | Objective 1b, change standard to read "by correctly identifying 10 out of 14 components." |
| VI | 71 | Objective 2b, change standard to read "by correctly answering 4 out of 5 questions." |
| VIII | 101 | Objective 6a, change standard to read "by correctly answering 5 out of 7 questions." |

POI J3ABR54532 001, Changed 20 September 1985.

WRITE-IN CHANGES EFFECTIVE DATE: 3 October 1985

| BLOCK | PAGE | ACTION |
|---|---|---|
| I | 15 | Add paragraph 8. MT: Physical Conditioning (Day 5) 2 |
| V | 56 | Under Training Methods, Change Lecture/Discussion to (3.5 hrs) and Add Performance (2.5 hrs). |
| V | 61 | Objective 4a, Delete STS Elements 13b(2), 13b(3), and 13b(4). |

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| | |
|---|---|
| NAME OF INSTRUCTOR | COURSE TITLE<br>Heating Systems Specialist |

BLOCK TITLE
Fundamentals and Pipefitting

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 1. Orientation | 2/0 |

a. Welcome

b. Overview of course content, its goals and administration

(1) Overview of course

(2) Course objectives and goals

(3) Course administration

c. Responsibilities of students

d. Relationship of graduate's performance to Air Force mission

e. Benefits of the CCAF and its assignments of academic credit for training completed at regional accredited institutions

f. Types and uses of instructional materials

g. Student progress policies to include:

(1) Progress checks

(2) Written tests

(3) Special individual assistance

(4) Proficiency advancement

(5) School grading

h. Student recognition program

i. Effective study technique

j. Safety precautions and appropriate instructions on personal protective type items (when not covered in training material)

SUPERVISOR APPROVAL OF LESSON PLAN

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k. Procedures for shelter exercises and fire evacuation plan

(1) Fire drill

(2) Tornado alert

(3) Nuclear alert

l. Student critique program and its objective

m. Conservation of training materials, resources and energy

n. Fraud, Waste and Abuse

o. Dispositon of eliminees

p. Instructions for completion of STTC Form 120, Processing Checklist for TDY student personnel

## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-I-1, Orientation
2ATCPT 52-11, Study Skills

Audiovisual Aids
Prenarrated Slide, NSS55-42, Student Critique Program
Prenarrated Slide, NSS00-44, Community College of the Air Force
Prenarrated Slide, NSS60-67, The Generality Barrier

Training Methods
Lecture/Discussion (2 hrs)

Instructional Guidance
Welcome students to course and introduce course, branch, group, and school personnel by name. Present course objective, administrative procedures, and policies by discussing each subject with the class.

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Fundamentals and Pipefitting

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 2. Civil Engineering Organization, Safety, and Publications | 4/2 |
| a. Given information, identify basic facts of CE mission and CE organization by correctly answering ~~a minimum of 70% of the~~ 2 out of 3 questions. STS: 1c Meas: PC<br>(1) Unit<br>(2) Squadrons<br>(3) Groups | (.5/0) |
| b. Given information, identify basic facts of progression in the 54 career field ladder, and duties and responsibilities of the 545X2 career field by correctly answering ~~a minimum of 70% of the~~ 6 out of 8 questions. STS: 1a, 1b Meas: PC | (0/1.5) |
| c. Given information, identify basic facts of work identification, work authorization, management and utilization of material resources by correctly answering ~~a minimum of 70% of the~~ 4 out of 6 questions. STS: 6a(3), 6a(4), 6b(1), 6b(2), 6f Meas: PC<br>(1) Work identification<br>(2) Work authorization<br>(3) Management and utilization of material resources | (1/0) |
| d. Given information, identify basic facts of AFOSH Standards and hazards of the 545X2 career field by correctly answering ~~a minimum of 70% of the~~ 6 out of 9 questions. STS: 3a, 3b Meas: PC<br>(1) AFR 0-17, AFOSH Standard Index<br>(2) Hazards of the 545X2 career field | (.5/0) |
| e. Given information, explain individual responsibilities toward safety standards by answering a minimum of 80% of the questions. STS: 3d Meas: PC | (.25/0) |

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f. Given information, determine safety practices when working with high intensity sound, flammables, chemicals, and acids by answering a minimum of 80% of the questions. STS: 3e(3), 3e(4), 3e(5), 3e(6) Meas: PC (.5/.25)

(1) High intensity sound

(2) Flammables

(3) Chemicals

(4) Acids

g. Given information, correctly determine first aid procedures for: electrical shock, control bleeding, traumatic shock, heat exhaustion and heat stroke by answering a minimum of 80% of the questions. STS: 3f(1), 3f(2), 3f(3), 3f(4) Meas: PC (.5/.25)

(1) Electrical shock

(2) Control bleeding

(3) Traumatic shock

(4) Heat exhaustion

(5) Heat stroke

h. Given information, identify basic facts about the two types of publication systems by correctly answering ~~a minimum of 70% of the~~ questions. STS: 4a, 4b Meas: PC 4 out of 6 (.5/0)

(1) Standard Publications

(2) Specialized

i. ~~Given information, name the publications that pertain to the 545X2 career field by correctly answering a minimum of 70% of the questions.~~ STS: 4c Meas: PC (.25/0)

Given AFM 85-12 and instructions, locate information on maintenance and inspection of heating equipment with instructor assistance.

(1) AFR 91-7, Heating

(2) AFM 85-12, Vol I

(3) AFM 85-12, Vol II

## SUPPORT MATERIAL AND GUIDANCE

### Student Instructional Materials

SG J3ABR54532 001-I-2, Civil Engineering Organization, Safety, and Publications
WB J3ABR54532 001-I-2, Civil Engineering Organization, Safety, and Publications
SG AFS 54, 55, 56, All Courses Safety
2ATCPT-9039-01, Civil Engineering Mechanical/Electrical Career Field (54)
AFM 85-12, Vols I and II, (See instructor Reference Materials)

### Audiovisual Aids

Transparencies

### Training Methods

Lecture/Discussion (4 hrs)
Directed Study (2 hrs)

### Instructional Guidance

The third hour you will lecture on and discuss CE mission, CE organization, 54 career ladder, duties and responsibilities of 545X2 career field, work identification, work authorization, management and utilization of material resources. You will lecture on and discuss AFOSH Standards, hazards of the 545X2 career, individual responsibilities toward safety, safety practices for electrical and mechanical equipment, and safety practices for high intensity sound, flammables, chemicals and acids. You will lecture on and discuss first aid procedures for electrical shock, control bleeding, traumatic shock, heat exhaustion, and heat stroke. You will lecture on and discuss the two types of publication systems, and name the publications that pertain to the 545X2 career fields and assignment for homework. The last two hours of the day will be used for Directed study.

Instructor Reference Materials:
AFR 85-1, Resources and Work Force Management
AFR 85-7, MAJCOM Engineer and Services Organization and Functions
  127-1, 4, 5, 6, 7, 9, 11, 12, 31, 38, 40, 43, AFOSH Standards in Lieu of AFR 127-101, Ground Accident Prevention Handbook
AFR 39-1, Airman Classification Regulation
  161-1, 2, 4, 8, AFOSH Standards in Lieu of AFR 127-101, Ground Accident Prevention Handbook
AFR 0-14, Civil Engineering Publications System
AFR 0-2, Air Force Regulation System
AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems
AFM 85-12, Vol II, Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization
AFR 91-7, Heating
TO-00-5-1, Air Force Tech Order System
TO 31-10-3, First Aid

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Fundamentals and Pipefitting

| 1. COURSE CONTENT | 2. TIME |
|---|---|

3. Tools 4/1

a. Given information, select, use and care for the appropriate hand tools, with a maximum of two instructor assists. STS: 3e(7), 7a, 7b, 7c Meas: PC (1.5/.5)

(1) Wrenches

(2) Screwdrivers

(3) Pipe wrenches

b. Given information, select, use and care for the appropriate special tools, with a maximum of two instructor assists. STS: 7d, 7e, 7f Meas: PC (1.5/.25)

(1) Wiring tool

(2) Fuse puller

(3) Line wrench

(4) Vises

(5) Bench grinder

c. Given information, select, use and care for the appropriate precision measuring instruments, with a maximum of two instructor assists. STS: 7g, 7h, 7i Meas: PC (1/.25)

(1) Inside and outside calipers

(2) Gasket cutter

(3) Wire gauge

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
2TPT-3200-01, Common Hand Tools
WB J3ABR54532 001-I-3, Tools

SUPERVISOR APPROVAL OF LESSON PLAN

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Audiovisual Aids
Transparencies

Training Methods
Lecture/Discussion (1 hr)
Demonstration (.5 hr)
Performance (2.5 hrs)
Directed Study (1 hr)

Instructional Guidance
The first hour, check Directed Study for previous day's work. Lecture on and discuss hand tools, special tools, and precision measuring instruments. Demonstrate how to select, use and care for the hand tools, special tools and precision measuring instruments. Observe students while they select, use and care for the hand tools, special tools, and precision measuring instruments.

Instructor Reference Materials:
TO 32-1-101, 151, 171, 201
AFM 85-12, Vol II, Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization
Modern Refrigeration and Air Conditioning Textbook

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| | |
|---|---|
| NAME OF INSTRUCTOR | COURSE TITLE<br>Heating Systems Specialist |

BLOCK TITLE
Fundamentals and Pipefitting

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 4. Pipefitting | 14/3 |

a. Given information, explain basic facts about the types and sizes of pipe and fittings, by correctly answering 70% of the questions. STS: 7g, 7h, 7i, 10a(2), 10a(3) Meas: PC (1/.5)

(1) Pipes

(2) Fittings

b. Given information, hand tools, and pipe, measure, cut and thread pipe, with a maximum of two instructor assists. STS: 7m, 7n, 7o, 10a(4), 10a(5), 10a(6) Meas: PC (3/.25)

(1) Measuring procedures

(2) Cutting procedures

(3) Threading procedures

c. Given procedures, mechanical threader and pipe, measure, cut, and thread a pipe nipple 12 inches long, with a maximum of three instructor assists. STS: [illegible], 7p, 7q, 7r, 10a(7), 10a(8) Meas: PC (1/.25)

(1) Cutting procedures

(2) Threading procedures

d. Given information, select, use, and care for installed shop equipment, with a maximum of two instructor assists. STS: 7p, 7q, 7r Meas: PC (.5/0)

(1) Types of installed equipment

(2) Operating instructions

(3) Maintenance procedures

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e. Given information, hand tools, pipe nipples and fittings, perform procedures for fabricating a piping system which will maintain system pressure with no visible leakage, with a maximum of two instructor assists. STS: 10a(9) Meas: PC (1.5/0)

(1) Selection of tools, pipe and fittings

(2) Procedures for fabricating a piping system

f. Given information, explain basic facts about types and sizes of valves, by correctly answering ~~70% of the~~ questions. STS: 10b(1), 10b(2) Meas: PC 6 out of 8 (.25/.5)

(1) Types of valves

(2) Sizes of valves

g. Given information, hand tools and valves, perform basic step-by-step procedures for doing simple maintenance on valves, with a maximum of two instructor assists. STS: 10b(3), 10b(4), 10b(5), 10b(6) Meas: PC (.25/0)

(1) Gate valves

(2) Globe valves

(3) Check valves

(4) Plug valves

h. Given information, identify basic facts about reinforced thermosetting resin pipe, by correctly answering ~~70% of the~~ questions. 6 out of 8 STS: 10d(1), 10d(2), 10d(3), 10d(4), 10d(5), 10d(6) Meas: PC (1/.5)

(1) Uses

(2) Types

(3) Measuring procedures

(4) Cutting procedures

(5) Connecting procedures

i. Given special tools and instructions, measure, cut and connect reinforced thermosetting resin pipe, with a maximum of three instructor assists. STS: 10d(4), 10d(5), 10d(6) Meas: PC (4/0)

(1) Measuring procedures

(2) Cutting procedures

(3) Connecting procedures

j. Given information, identify basic facts about cross-connection, backflow by correctly answering 80% of the questions. STS: 3h Meas: PC (.25/.5)

(1) Cross connection

(2) Backflow

k. Given information, identify basic facts about hazardous piping, by correctly answering 80% of the questions. STS: 10e(1), 10e(2), 10e(3), 10e(4) Meas: PC (.25/.5)

(1) Air

(2) Fuel oil

(3) Gas

(4) Steam

l. Given information, blueprints, drawings and symbols, determine step-by-step procedures for interpret~~ing~~ blueprints and drawings, ~~with~~ by ~~a maximum of two instructor assists~~ answering ~~80% of the~~ questions correctly. STS: 10a(1) Meas: PC (1/0)

(1) Blueprints

(2) Care of blueprints

(3) Lines used on blueprints

(4) Scaling

(5) Symbols

## SUPPORT MATERIALS AND GUIDANCE

**Student Instructional Materials**
SG J3ABR54532 001-I-4, Pipefitting
WB J3ABR54532 001-I-4, Pipefitting

## COURSE CONTENT

**Audiovisual Aids**

35mm Slide Presentation
Transparencies
Training Film: SAFB-213-B, Piping Safety

**Training Equipment**

Hand tools
Pipe and Fittings
Valves
Special tools for cutting and threading pipe
Special tools for cutting and connecting thermosetting resin pipe

**Training Methods**

Lecture/Discussion (4 hrs)
Demonstration (1.5 hrs)
Performance (8.5 hrs)
Directed Study (3 hrs)

**Instructional Guidance**

Instruct students on types and sizes of pipes and fittings; on measuring, cutting and threading pipe by hand and power threader and cutters. Teach proper methods for servicing power threader. Demonstrate proper procedures using hand and power cutter and threader. Observe students while they cut, thread and connect piping. Identify types and sizes of valves. Demonstrate proper maintenance of valves. Observe students while they perform maintenance on valves. Identify basic facts about reinforced thermosetting pipe. Demonstrate procedures for connecting thermosetting resin pipe. Observe students' connection of thermosetting resin pipe. Identify basic facts about cross-connection/backflow. Identify basic facts about hazardous piping used in the heating career field in accordance with ground safety regulations. Demonstrate procedures required to understand blueprint drawings and symbols. Check Directed Study each morning and sign off all criterion objectives when completed.

Instructor Reference Materials:
AFM 85-12, Vol II, Operation and Maintenance of Space Heating Equipment and System, and Process Heat Utilization
AFM 91-6, Maintenance and Operation of Gas Systems
AFM 85-21, Operation and Maintenance of Cross-Connection Control and Backflow Prevention Devices

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Fundamentals and Pipefitting

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 5. Principles of Heating | 4.5/0 |
| a. Given information, identify basic facts of the structure of matter and thermodynamics, by correctly answering 70% of the questions. STS: 12a, 12b, 12c, 12d, 12e, 12f, 12g, 12i, 12k Meas: PC<br>(1) Matter<br>(2) Thermodynamics | (2.5/0) |
| b. Given information, identify basic facts of the laws of gases, by correctly answering ~~70% of the~~ 2 out of 3 questions. STS: 12h Meas: PC<br>(1) Boyles' Law<br>(2) Charles' Law<br>(3) Dalton's Law | (.5/0) |
| c. Given information, identify basic facts of metric conversion, by correctly answering ~~70% of the~~ 2 out of 3 questions. STS: 12j Meas: PC<br>(1) Temperature<br>(2) Length<br>(3) Weight<br>(4) Volume | (1.5/0) |

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-I-5, Principles of Heating
WB J3ABR54532 001-I-5, Principles of Heating

Audiovisual Aids
Transparencies

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Training Methods
Lecture/Discussion (3 hrs)
Demonstration (.5 hr)
Performance (1 hr)

Instructional Guidance
Instruct students on basic structure of matter. Explain thermodynamics and how it applies to heating. Discuss application of Boyles', Charles' and Dalton's Laws. Discuss and demonstrate the procedures used in metric conversion for temperature, length, weight and volume. Summarize complete block and explain how it fits in with the remainder of the course.

Instructor Reference Materials:
Textbook, Modern Refrigeration and Air Conditioning

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| | |
|---|---|
| NAME OF INSTRUCTOR | COURSE TITLE<br>Heating Systems Specialist |
| BLOCK TITLE<br>Fundamentals and Pipefitting | |

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 6. EPS Awareness | 0/2 |

a. Given information on EPS, develop a working knowledge of engineered performance standards by answering 7 out of 10 questions correctly. STS: 6b(3) Meas: PC

SUPPORT MATERIALS AND GUIDANCE

Student Instructional Materials
Directed Study, Engineered Performance Standards

Training Methods
Directed Study (2 hrs)

Instructional Guidance
Handout Directed Study book on EPS on the fourth day of course and give progress check at beginning of Day 5.

| | |
|---|---|
| 7. Written Test and Test Critique | 1.5 |
| a. Written Test | (1.0) |
| b. Test Critique | (0.5) |
| 8. MT: Physical Conditioning (Day 5) | 2 |

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## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
|  | Heating Systems Specialist |

BLOCK TITLE
Basic Electricity

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 1. Electrical Fundamentals | 6/2 |
| a. Given information, identify basic facts relating to electrical fundamentals, by correctly answering 70% of the questions.<br>STS: 8a, 8e Meas: PC<br>(1) Electron theory<br>(2) Voltage<br>(3) Current<br>(4) Resistance<br>(5) Electrical wiring practices<br>(6) Controlling electricity<br>(7) Electrical symbols and diagrams | (5/2) |
| b. Given fuses, fuse puller and fused safety switch, install circuit protective devices with a maximum of two instructor assists.<br>STS: 3e(1), 8g(2) Meas: PC | (1/0) |

SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-II-1, Electrical Fundamentals
WB J3ABR54532 001-II-1, Electrical Fundamentals

Audiovisual Aids
Transparencies, Electrical Fundamentals
Training Film, Wire Size and Voltage Drop

Training Methods
Lecture/Discussion (5 hrs)
Demonstration (.5 hr)
Performance (.5 hr)
Directed Study (2 hrs)

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Instructional Guidance
Discuss basic facts about electrical fundamentals relationship between voltage current and resistance, wiring practices and controlling devices. Explain purpose and types of circuit protective devices. Give Directed Study assignment on Electrical Fundamentals.

Instructor Reference Materials:
AFP 85-1, Electrical Facilities Safe Practice Handbook

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE<br>Heating Systems Specialist |
|---|---|

BLOCK TITLE
Basic Electricity

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 2. Theory of Magnetism and Transformers | 3/1 |

a. Given information, identify basic facts relating to the theory of magnetism and transformers, by correctly answering 70% of the questions. STS: 8c Meas: PC

(1) Magnetism

(2) Electromagnetism

(3) Transformers

SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-II-2, Theory of Magnetism and Transformers
WB J3ABR54532 001-II-2, Theory of Magnetism and Transformers

Audiovisual Aids
Transparencies, Theory of Magnetism and Transformers

Training Equipment
Magnets
Solenoid Valves
Control Relays
Control Transformers
Ignition Transformers

Training Methods
Lecture/Discussion (2 hrs)
Demonstration (.5 hr)
Performance (.5 hr)
Directed Study (1 hr)

Instructional Guidance
Discuss theory of Magnetism and Transformers. Explain and demonstrate magnetism, electromagnetism, and transformers. Explain permanent and temporary magnets, electromagnets, and their relationship to transforming electricity.

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## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Basic Electricity

| 1. COURSE CONTENT | 2. TIME |
|---|---|

3. Types and Characteristics of Electrical Circuits 6/2

a. Given information, identify basic facts relating to types and characteristics of electrical circuits, by correctly answering 70% of the questions. STS: 8b(1), 8b(2), 8b(3), 8d(1), 8d(2), 8d(3), 8e 8g(4) Meas: PC (3/1)

(1) Basic electrical circuits

(2) Ohm's Law for DC circuits

(3) Characteristics of series and parallel circuits

(4) Characteristics of series-parallel circuits

b. Using electrical circuit trainer, construct electrical circuits, with a maximum of two instructor assists. STS: 3e(1), 8g(3), 8g(4) Meas: PC (3/1)

(1) Electrical safety

(2) Simple circuit

(3) Series circuit

(4) Parallel circuit

(5) Series-parallel circuit

SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-II-3, Types and Characteristics of Electrical Circuits
WB J3ABR54532 001-II-3, Types and Characteristics of Electrical Circuits

Audiovisual Aids
Transparencies, Types and Characteristics of Electrical Circuits

Training Equipment
Electrical Circuit Trainers

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Training Methods
Lecture/Discussion (2 hrs)
Demonstration (1.5 hrs)
Performance (2.5 hrs)
Directed Study (2 hrs)

Instructional Guidance
Discuss types and characteristics of electrical circuits. Explain and demonstrate the use of Ohm's Law as it relates to electrical circuits. Demonstrate construction of simple, series, parallel, and series-parallel circuits. Emphasize the use of electrical safety practices when working with electrical equipment. Give Directed Study assignment on Types and Characteristics of Electrical Circuits.

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Basic Electricity

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 4. Electrical Wiring Diagrams | 3/1 |

4. Electrical Wiring Diagrams

a. Using electrical drawings, trace electrical circuits to determine operating characteristics, by answering correctly 70% of the questions. STS: 8g(1) Meas: PC

SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-II-4, Electrical Wiring Diagrams
WB J3ABR54532 001-II-4, Electrical Wiring Diagrams

Audiovisual Aids
Transparencies, Electrical Wiring Diagrams

Training Methods
Lecture/Discussion (1 hr)
Demonstration (.5 hrs)
Performance (1.5 hrs)
Directed Study (1 hr)

Instructional Guidance
Discuss basic facts relating to electrical wiring diagrams and symbols. Explain procedures for reading and using electrical drawings. Explain the electrical symbols used in electrical drawings. Give Directed Study assignment on Electrical Wiring Diagrams.

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## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Basic Electricity

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 5. Electrical Test Equipment | 3/1 |
| a. Using multimeter, select, care and use the ohmmeter function (continuity), by correctly identifying the resistance characteristics of 70% of the electrical devices. STS: 7s, 7t, 7u, 8g(4) Meas: PC | (1/.25) |
| b. Using multimeter, select, care and use the voltmeter function, by correctly identifying the voltage characteristics of 70% of the electrical devices. STS: 7s, 7t, 7u, 8g(4) Meas: PC | (1/.5) |
| c. Using multimeter, select, care and use the ammeter function, by correctly identifying the amperage characteristics of ~~70% of the~~ 3 out of 4 electrical devices. STS: 7s, 7t, 7u, 8g(4) Meas: PC | (1/.25) |

### SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-II-5, Electrical Test Equipment
WB J3ABR54532 001-II-5, Electrical Test Equipment

Audiovisual Aids
Transparencies, Electrical Test Equipment

Training Equipment
Multimeters
Continuity Training Aids

Training Methods
Lecture/Discussion (.5 hr)
Demonstration (.5 hr)
Performance (2 hrs)
Directed Study (1 hr)

Instructional Guidance
Explain the uses of different electrical test equipment. Discuss uses of ohmmeter, voltmeter, and ammeter. Demonstrate proper maintenance procedures and uses of meters. Demonstrate procedures for determining voltage, current and resistance.

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## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
|  | Heating Systems Specialist |

BLOCK TITLE
Basic Electricity

| 1. COURSE CONTENT | 2. TIME |
|---|---|

6. Electrical Motors and Motor Starters 7.5/1

a. Given information, identify basic facts relating to electrical motors and motor starters, by correctly answering 70% of the questions. STS: 8f(1), 8f(7), 8f(8) Meas: PC (2/1)

(1) Basic construction features of electric motors

(2) Theory of operation of electric motors

(3) Terminology

(4) Motor starters and overload protectors

(5) Motor safety

b. Using a trainer, remove and replace electric motor, with a maximum of two instructor assists. STS: 3e(2), 3e(7), 8f(2), 8f(3), 8f(4) Meas: PC (2/0)

(1) Removal procedures

(2) Replacement procedures

c. Using the single-phase and three-phase motor trainers, reverse the motor rotation, with a maximum of two instructor assists. STS: 3e(2), 8f(4), 8f(5) Meas: PC (2/0)

(1) Single-phase

(2) Three-phase

d. Using the three-phase motor trainer, inspect and maintain motor, with a maximum of two instructor assists. STS: 3e(2), 8f(6) Meas: PC (1.5/0)

### SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-II-6, Electrical Motors and Motor Starters
WB J3ABR54532 001-II-6, Electrical Motors and Motor Starters

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Audiovisual Aids
Transparencies, Electrical Motors and Motor Starters

Training Equipment
Single-Phase and Three-Phase Motor Trainers
Multimeters
Hand Tools
Furnace Blower Assemblies

Training Methods
Lecture/Discussion (2.5 hrs)
Demonstration (.5 hr)
Performance (4.5 hrs)
Directed Study (1 hr)

Instructional Guidance
Discuss electrical motors and motor starters and their uses in heating systems. Discuss and demonstrate basic construction features of electrical motors. Explain theory of operation of motors. Discuss motor protection devices. Explain procedures for removing and replacing electrical motors. Demonstrate procedures used to reverse rotation of single-phase and three-phase motors. Discuss maintenance procedures for electrical motors. Discuss safety when working with electrical motors. Give Directed Study assignment on Electrical Motors and Motor Starters.

| | | |
|---|---|---|
| 7. | Written Test and Test Critique | 1.5 |
| | (a) Written Test | (1) |
| | (b) Test Critique | (.5) |
| 8. | MT: Physical Conditioning (Day 10) | 2 |

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Controls, Troubleshooting and Oil Burners

1. COURSE CONTENT — 2. TIME

1. Electrical and Electronic Controls 7/2

a. Using information given, explain facts about the purpose, use of and principles of operation of electrical controls, by correctly answering 70% of the questions. STS: 9a(1)(a), 9a(1)(b), 9a(2), 9a(3) Meas: PC (3/1.0)

(1) Purpose of electrical controls

(2) Use of electrical controls

(3) Principles of operation

b. Given tools and equipment, adjust electrical controls to assure proper operation with instructor assistance. STS: 3e(7), 9a(4) Meas: PC (1.0/.25)

(1) Adjustment procedures

(2) Safety

c. Using information given, identify basic facts relating to electronic controls, by correctly answering 70% of the questions. STS: 9b(1), 9b(2) Meas: PC (1.5/.25)

(1) Purpose of electronic controls

(2) Use of electronic controls

d. Using information given, identify the facts about the theory of operation and use of pneumatic controls by correctly answering 70% of the questions. STS: 9c(1), 9c(2) Meas: PC (1/.25)

(1) Theory of operation

(2) Use of pneumatic controls

e. Using information given, explain the basic procedures to remove, replace, adjust, maintain and troubleshoot pneumatic controls and equipment, and how to install pneumatic control pipes, tubes and valves, by correctly answering 70% of the questions. STS: 9c(3), 9c(4), 9c(5), 9c(6), 9c(7), 9c(8) Meas: PC (.5/.25)

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(1) Procedures to remove, replace, adjust and maintain pneumatic controls

(2) Troubleshooting pneumatic controls and equipment

(3) Installation of control pipes, tubes and valves

## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-III-1, Electrical and Electronic Controls
WB J3ABR54532 001-III-1, Electrical and Electronic Controls

Audiovisual Aids
Transparencies, Electrical Controls

Training Equipment
Trainer, Warm Air Furnace, Low-Voltage Circuit
Trainer, Warm Air Furnace, Line-Voltage Circuit
Trainer, Control System Hot Water Boiler
Trainer, Electronic Flame Safeguard

Training Methods
Lecture/Discussion (6.0 hrs)
Demonstration (.5 hr)
Performance (.5 hr)
Directed Study (2.0 hrs)

Instructional Guidance
Have all trainers and equipment available and emphasize safety when working with the trainers. Explain the purpose of and use of electrical controls and the principles of operation of two-position and modulating controls. Talk about and show the different types of controls used in the heating field. After you have finished this, take the students to the lab and have them adjust the heat anticipator on a thermostat. Once you have completed this, continue on by telling the students about the basic facts relating to electronic controls and how and where we use them in heating. Using transparencies, show the students the pneumatic control system and explain the theory of operation and use of pneumatic controls. Explain the basic procedures to remove, replace, adjust, maintain, and troubleshoot pneumatic controls and equipment and how to install pneumatic control pipes, tubes and valves. Directed Study assignments for this objective will be given at the end of day 11. Check for completion of exercises at the start of day 12.

Instructor Reference Materials:
Electric Controls for Refrigeration and Air Conditioning by B. C. Langley
Electric Control Circuits by Minneapolis-Honeywell Regulator Company
Technical Data File No. 77-1014, Modern Refrigeration and Air Conditioning
Commercial/Industrial Flame Safeguard Controls by Honeywell
RA890 and R4795 Honeywell Service Handbook
AFM 85-12, Vol II, Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization

PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Controls, Troubleshooting and Oil Burners

| 1. COURSE CONTENT | 2. TIME |
|---|---|

2. Troubleshooting of Electrical Controls 5/2 (2.5/1)

a. ~~Using information given,~~ Given ~~explain the~~ step-by-step procedures, ~~necessary to~~ troubleshoot electrical controls on a warm air furnace, trainer ~~by correctly answering 70% of the questions~~. STS: 7g, 7h, 7i, 9a(5), [illegible] Meas: PC with instructor assistance. ~~(.5/.5)~~

~~(1) Troubleshooting procedures of electrical controls~~

~~(2) Troubleshooting procedures of safety control systems~~

b. Given tools and equipment, trace electrical circuits, isolate electrical malfunctions, and perform minor repairs to electrical circuits, with instructor assistance. STS: 3e(2), 8g(5), 8g(4) 8g(6) Meas: PC (2.5/1) ~~(4.5/1.5)~~

(1) Tracing of electrical circuits using diagrams and drawings

(2) Isolating of electrical malfunctions

(3) Minor repair procedures of electrical circuits and units

(4) Electrical and mechanical safety

SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-III-2, Troubleshooting of Electrical Controls
WB J3ABR54532 001-III-2, Troubleshooting of Electrical Controls

Audiovisual Aids
Transparencies, Electrical Circuits and Controls

Training Equipment
Trainer, Warm Air Furnace, Low-Voltage Circuit
Trainer, Warm Air Furnace, Line-Voltage Circuit
Trainer, Warm Air Furnace
Multimeter

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Training Methods
Lecture/Discussion (0.5 hrs)
Demonstration (.5 hr)
Performance (4.0 hr)
Directed Study (2.0 hrs)

Instructional Guidance
Have all trainers and equipment available and emphasize safety when working with the trainers. Explain and demonstrate the step-by-step procedures necessary to troubleshoot electrical methods, trace electrical circuits, isolate electrical malfunctions and perform minor repairs to electrical circuits. Directed Study assignments for this objective will be given at the end of day 12. Check for completion of exercises at the start of day 13.

Instructor Reference Materials:
Croft's American Electrician's Handbook, Eighth Edition, by McGraw-Hill

## PLAN OF INSTRUCTION/LESSON PLAN PART I

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|---|---|
| NAME OF INSTRUCTOR | COURSE TITLE<br>Heating Systems Specialist |
| BLOCK TITLE<br>Controls, Troubleshooting and Oil Burners | |

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 3. Combustion Efficiency and Draft | 4/1 |

a. Using information given, perform combustion analysis and compute combustion efficiency to within ± 5% of the instructor results. STS: 7g, 7h, 7i, 7j, 7k, 7l, 7m, 7n, 7o, 14j, 14k Meas: PC (3.5/.5)

(1) Procedures for performing combustion analysis

(2) Computation of combustion efficiency

b. Using information given, explain the procedures necessary to adjust stack draft to assure proper combustion by correctly answering 80% of the questions. STS: 14d Meas: PC (.5/.5)

(1) Purpose of draft

(2) Measurement of draft

### SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-III-3, Combustion Efficiency and Draft
WB J3ABR54532 001-III-3, Combustion Efficiency and Draft

Audiovisual Aids
Transparencies, Computing Fuel Requirements
Slide Set

Training Equipment
Trainer, Gas Fired Warm Air Furnace
Trainer, Oil Fired Warm Air Furnace
Trainer, Flue Gas Analyzers

Training Methods
Lecture/Discussion (1.5 hr)
Demonstration (.5 hr)
Performance (2.0 hr)
Directed Study (1 hr)

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Instructional Guidance
Have all trainers and equipment available and emphasize safety when working with the analyzers. Explain and demonstrate the step-by-step procedures necessary to perform combustion analysis, compute combustion efficiency, and adjust stack draft. Emphasize energy conservation throughout lesson. Make sure all trainers and equipment have been secured. Directed Study assignments for this objective will be given at the end of day 13. Check for completion of exercises at the start of day 14.

Instructor Reference Materials:
AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Controls, Troubleshooting and Oil Burners

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 4. Domestic and Industrial Oil Burners | 13/3 |
| a. Using information given, explain the characteristics of oil, theory of gravity and forced fuel oil supply system, and the theory of construction and operation of rotary pumps by correctly answering 80% of the questions. STS: 13c(1), 15a, 15h Meas: PC | (1/1) |
| (1) Characteristics of oil | |
| (2) Theory of gravity and forced fuel oil supply systems | |
| (3) Theory of construction and operation of rotary pumps | |
| b. Given information, tools and equipment, install, operate and maintain rotary pumps with instructor assistance. STS: 3e(2), 3e(4), 13c(2), 13c(3), 13c(4) Meas: PC | (.75/ .25) |
| (1) Installation | |
| (2) Operation | |
| (3) Maintenance | |
| (4) Safety | |
| c. Using information given, explain the procedures necessary to install fuel oil piping systems and storage tanks, by correctly answering 80% of the questions. STS: 15k Meas: PC | (.5/.5) |
| (1) Components of fuel oil storage tanks | |
| (2) Fuel oil storage tanks | |
| (3) Types of fuel oil piping systems | |
| d. Given information, tools and equipment, inspect and maintain fuel oil piping systems and storage tanks, and determine the quantity of fuel in tank with instructor assistance. STS: 3e(4), 15i, 15j, 15l Meas: PC | (.75/0) |

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(1) Inspection of fuel oil piping systems and storage tanks

(2) Maintenance of fuel oil piping systems and storage tanks

(3) Measurement of fuel oil in tanks

(4) Safety

e. Using information given, explain the theory of construction and principles of operation of domestic and industrial oil burners, by correctly answering 80% of the questions. STS: 17a(1), 17a(2) Meas: PC (2.0/ 1.25)

(1) Theory of construction

(2) Principles of operation

f. Given information, tools and equipment, perform preoperational checks; operate, adjust, maintain, troubleshoot, and replace oil burners with instructor assistance. STS: 3e(2), 3e(4), 17c, 17d, 17e, 17f, 17g, 17h, 20b, 20c Meas: PC (6.0/0)

(1) Preoperational inspection

(2) Operation procedures

(3) Adjustment procedures

(4) Maintenance

(5) Troubleshooting procedures

(6) Replacement procedures

(7) Safety

g. Given information, tools and equipment, remove and install electrical controls on an oil fired warm air furnace, with instructor assistance. STS: 9a(6), 9a(7) Meas: PC (.75/0)

(1) Removal procedures

(2) Installation procedures

(3) Electrical safety

h. Given information, tools and equipment, remove, install and service blowers; inspect, adjust, align and replace couplings, pulleys, and drive belts on a warm air furnace with instructor assistance. STS: 3e(7), 20e(1), 20e(2), 20e(3), 20e(4), 20e(5), 20e(6), 20e(7) Meas: PC (.75/0)

(1) Removal, installation, and servicing of blowers

(2) Inspection, adjustment, alignment and replacement of couplings, pulleys and drive belts

(3) Safety

i. Given information, tools and equipment, remove, install a warm air furnace, connect exhaust outlets to flues or stacks, and adjust fuel-air ratio for proper combustion efficiency on an oil burner with instructor assistance. STS: 3e(2), 3e(7), 17i, 19d, 19e, 19n Meas: PC (.5/0)

(1) Furnace removal procedures

(2) Installation of furnaces

(3) Connection of exhaust outlets to flues or stacks

(4) Adjustment of fuel-air ratio for proper combustion efficiency

## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-III-4, Domestic and Industrial Oil Burners
WB J3ABR54532 001-III-4, Domestic and Industrial Oil Burners

Audiovisual Aids
Transparencies, Oil Burners
Film, Oil Burners

Training Equipment
Trainer, Oil Burner
Trainer, Oil Fired Warm Air Furnace
Trainer, Gas Flue Analyzer

Training Methods
Lecture/Discussion (6.0 hrs)
Demonstration (1.0 hr)
Performance (6.0 hr)
Directed Study (3 hrs)

Instructional Guidance

Have all equipment and trainers available and emphasize safety when working with the trainers. Explain the characteristics of oil, the different types of oil piping systems and their components and how to maintain them. Take class to the lab and have them dip the fuel oil tank. Using transparencies, show the students the different types of fuel oil pumps and their operation. Explain about the different the types of industrial and domestic oil burners and their operation. Demonstrate to the students how to properly remove, disassemble, clean, reassemble, and operate the domestic gun burner. Explain and demonstrate how to remove, install and service blowers. Go over the proper procedures used to inspect, adjust, align and replace couplings, pulleys and drive belts. Once you have completed all the above, take the class to the lab and demonstrate how to remove and install a warm air furnace and how to properly connect exhaust outlets to flues or stacks. After demonstrating, have the class do Exercise 1 in the Workbook. Directed Study assignments for this objective will be given at the end of day 13. Check for completion of exercises at the start of days 14 and 15.

Instructor Reference Materials:
AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems
Domestic and Commercial Oil Burners (Third Edition) by McGraw-Hill

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Controls, Troubleshooting and Oil Burners

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 5. Oil Fired Space Heaters | 2.5/0 |

a. Given information, determine the step-by-step procedures for removing, installing and maintaining oil fired space heaters, by correctly answering 80% of the questions. STS: 19f, 19g, 19h
Meas: PC

(1) Types and applications of oil fired space heaters

(2) Construction features and controls

(3) Procedures for removing and installing

(4) Procedures for operating and maintaining

SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-III-5, Oil Fired Space Heaters
WB J3ABR54532 001-III-5, Oil Fired Space Heaters

Audiovisual Aids
Transparencies, Oil Space Heaters

Training Equipment
Trainer, Oil Space Heater
Trainer, Fuel Oil Control Valve

Training Methods
Lecture/Discussion (2.5 hrs)

Instructional Guidance
Discuss the different types of oil fired space heaters and their applications. Explain the step-by-step procedures necessary to remove, install and maintain an oil fired space heater. Explain the purpose of the fuel oil control valve and its components.

Instructor Reference Materials:
AFM 85-12, Vol II, Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization
T.O. 40H30506021, Harvest Eagle Kit
ASHRAE Guide and Data Book, Equipment 1972

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|---|---|
| 6. Written Test and Test Critique | 1.5 |
| (a) Written Test | (1.0) |
| (b) Test Critique | (0.5) |
| 7. MT: (Physical Conditioning) (Day 15) | 2 |

## PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR

COURSE TITLE
Heating Systems Specialist

BLOCK TITLE
Solid, Gas Fuel Burners, and Warm Air Distribution Systems

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 1. Gas Burners | 9/4 |
| a. Given information, explain the characteristics of gas, and theory of construction and operation of domestic, industrial and biomass gas burners by correctly answering 80% of questons. STS: 15a, 18a(1), 18a(2), 18a(3) Meas: PC | (3/2) |
| (1) Characteristics of gas | |
| (2) Theory of construction, operation of gas burners, and components | |
| b. Given tools and equipment, perform preoperational checks, replace and maintain gas burners, replace appliance pressure regulators, determine gas pressure, adjust pressure regulators and adjust fuel-air ratio for proper combustion efficiency with instructor assistance. STS: 3e(2), 3e(4), 3e(7), 3e(10), 18b, 18c, 18d, 18e, 18f, 18g, 18m, 18n, 20b, 20c Meas: PC | (6/2) |
| (1) Preoperational checks | |
| (2) Replacement of gas burners | |
| (3) Maintenance of gas burners | |
| (4) Replacement of appliance pressure regulators | |
| (5) Measurement of gas pressure | |
| (6) Adjustment of pressure regulators | |
| (7) Adjustment of fuel-air ratio for proper combustion efficiency | |
| (8) Safety | |

SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-IV-1, Gas Burners
WB J3ABR54532 001-IV-1, Gas Burners

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Audiovisual Aids
Transparencies, Gas Burners
Tape Slide Presentation

Training Equipment
Trainer, Gas Fired Warm Air Furnace
Trainer, Manometer

Training Methods
Lecture/Discussion (4 hrs)
Demonstration (1 hr)
Performance (4 hrs)
Directed Study (4 hrs)

Instructional Guidance
Have all trainers and equipment available and emphasize safety when working with the trainers. Explain the characteristics of gas and the theory of construction and operation of domestic, industrial and biomass gas burners. Explain the purpose and operation of automatic gas valves and gas pressure regulators. Demonstrate the procedures to follow to perform preoperational checks, how to measure gas pressure using the manometer and how to adjust, replace and maintain regulators. After the students have performed all of the above, have them perform a combustion analysis and adjust the fuel-air ratio to assure proper combustion efficiency. Directed Study assignments for this objective will be given at the end of day 16. Check for completion of exercise at the start of day 17.

Instructor Reference Materials:
AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems
Natural Gas Distribution, a Home Study Course by Southern Gas Association
AFM 91-6, Maintenance and Operation of Gas Systems

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE<br>Heating Systems Specialist |
|---|---|

BLOCK TITLE
Solid, Gas Fuel Burners, and Warm Air Distribution Systems

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 2. Gas Space Heaters | 3/1 |

2. Gas Space Heaters

a. Given information, equipment and tools, remove, install and maintain a gas fired space heater, with instructor assistance.
STS: 3e(4), 3e(7), 19i, 19j, 19k Meas: PC

(1) Types and applications of gas space heaters

(2) Construction features and controls

(3) Procedures for removing and installing

(4) Procedures for operating and maintaining

(5) Safety

### SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-IV-2, Gas Space Heaters
WB J3ABR54532 001-IV-2, Gas Space Heaters

Audiovisual Aids
Transparencies, Gas Space Heaters

Training Equipment
Trainer, Gas Fired Space Heater

Training Methods
Lecture/Discussion (1 hr)
Demonstration (.5 hr)
Performance (1.5 hrs)
Directed Study (1 hr)

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Instructional Guidance

Have all trainers and equipment available and emphasize safety when working with the trainers. Explain the different types of gas space heaters and their applications. Talk about the construction features and controls. Once you have completed this, take the students to the lab and demonstrate the procedures for removing, installing and maintaining gas space heaters. Directed Study assignments for this objective will be given at the end of day 17. Check for completion of exercise at the start of day 18.

Instructor Reference Materials:

AFM 85-12, Vol II, Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE<br>Heating Systems Specialist |
|---|---|

BLOCK TITLE
Solid, Gas Fuel Burners, and Warm Air Distribution Systems

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 3. Unit Heaters | 3/1 |

3. Unit Heaters

a. Given information, equipment and tools, remove, install and maintain unit heaters with instructor assistance. STS: 3e(4), 3e(7), 19a, 19b, 19c Meas: PC

(1) Types and applications of unit heaters

(2) Construction features

(3) Procedures for removing and installing unit heaters

(4) Procedures for operating and maintaining unit heaters

(5) Safety

SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-IV-3, Unit Heaters
WB J3ABR54532 001-IV-3, Unit Heaters

Audiovisual Aids
Transparencies, Unit Heaters

Training Equipment
Trainer, Gas Fired Space Heater
Trainer, Hot Water Unit Heater

Training Methods
Lecture/Discussion (1 hr)
Demonstration (.5 hr)
Performance (1.5 hrs)
Directed Study (1 hr)

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Instructional Guidance

Have all trainers and equipment available and emphasize safety when working with the trainers. Using transparencies, talk about the different types and applications of unit heaters and their construction features. Once you have completed this, take the students to the lab and demonstrate the procedures for removing, installing and operating a gas fired unit heater. Directed Study assignments for this objective will be given at the end of day 18. Check for completion of exercise at the start of day 19.

Instructor Reference Materials:

AFM 85-12, Vol II, Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Solid, Gas Fuel Burners, and Warm Air Distribution Systems

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 4. Forced Warm Air Heating Systems | 6/2 |
| a. Given information, state the principles relating to the theory of operation and construction of warm air heating systems by correctly answering 80% of the questions. STS: 20a Meas: PC<br>(1) The purpose of a warm air furnace<br>(2) Types of warm air furnaces<br>(3) Construction features of warm air furnaces<br>(4) Operation of warm air furnaces | (2.75/ .5) |
| b. Given information, explain the procedures to follow to inspect, clean, and install heating outlets to system, repair or replace duct insulating material, how to inspect and adjust distribution dampers and balance distribution system, and how to inspect and adjust air registers by correctly answering ~~10 out of 12~~ 80% of the questions. STS: 20d, 20g(1), 20g(2), 20g(3), 20g(4), 20g(5), 20g(6), 20g(7), 20g(8) Meas: PC<br>(1) Inspection and cleaning of warm air ducts<br>(2) Repair or replacement of duct insulating material<br>(3) Inspection and adjustment of distribution dampers<br>(4) Balancing air distribution system<br>(5) Inspection and adjustment of war air registers | (1.0/ .75) |
| c. Given information, explain the procedures to follow to inspect, remove, clean and replace heat exchangers and how to maintain humidifiers, by correctly answering 80% of the questions. STS: 20h, 20i, 20j, 20k, 20l Meas: PC<br>(1) Inspection of heat exchangers<br>(2) Removal of heat exchangers | (.25/ .25) |

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(3) Cleaning of heat exchangers

(4) Replacement of heat exchangers

(5) Maintenance of humidifiers

d. Given information, explain the purpose of air filters and the types of air filters by correctly answering 80% of the questions. STS: 20f(1), 20f(2) Meas: PC (.5/.25)

(1) Purpose of air filters

(2) Types of air filters

e. Given tools, equipment and procedures, perform a preoperational inspection and operate a warm air heating system and inspect, clean and replace warm air filters with instructor assistance. STS: 3e(2), 20b, 20c, 20f(3), 20f(4), 20f(5) Meas: PC (0.5/.25)

(1) Inspection of air filters

(2) Cleaning of air filters

(3) Replacing air filters

f. Given tools and equipment, connect warm air outlet to system with instructor assistance. STS: 19o(1), 19o(2) Meas: PC (1/0)

(1) Installation of ducts

(2) Installation of pipes

## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-IV-4, Forced Warm Air Heating Systems
WB J3ABR54532 001-IV-4, Forced Warm Air Heating Systems

Audiovisual Aids
Transparencies, Forced Warm Air Heating Systems

Training Equipment
Trainer, Gas Fired Warm Air Furnace
Trainer, Oil Fired Warm Air Furnace

Training Methods
Lecture/Discussion (4 hrs)
Demonstration (1.5 hr)
Performance (.5 hr)
Directed Study (2 hrs)

Instructional Guidance

Have all trainers and equipment available and emphasize safety when working with the trainers. Using transparencies, talk about the theory of operation and construction of warm air furnaces and systems. Show the different types of warm air furnaces, their construction features and operation. Explain the purpose of the warm air distribution system, the different types and how to inspect and maintain them. Talk about the distribution dampers and their purpose. Explain to the students the purpose of a humidifier, the different types, their advantages and disadvantages, and how to maintain them. Show the different types of air filters and their purpose. After you have finished talking about air filters, take the students to the lab, demonstrate how to properly inspect, clean and replace filters, then have them do the same. Directed Study assignments for this objective will be given at the end of day 19. Check for completion of exercise at the start of day 20. Have students disconnect, inspect and reconnect heating outlets with instructor assistance.

Instructor Reference Materials:
AFM 85-12, Vols I and II, Operation and Maintenance of Control Heating Plants
and Distribution Systems, and Operation and Maintenance of Space Heating
Equipment and Systems, and Process Heat Utilization
Modern Refrigeration and Air Conditioning Textbook
ASHRE Handbook, 1977, Fundamentals

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Solid, Gas Fuel Burners, and Warm Air Distribution Systems

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 5. Solid Fuel Burners | 4.5/0 |
| a. Using information given, explain the characteristics of coal by correctly answering 80% of the questions. STS: 15a Meas: PC<br>(1) Coal defined<br>(2) Characteristics of coal | (.5/.0) |
| b. Given information, explain the procedures to follow to maintain coal storage areas, inspect coal shipments, collect and prepare coal samples for analysis and inspect coal handling equipment by correctly answering 80% of the questions. STS: 15c, 15d, 15e, 15f, 15g Meas: PC<br>(1) Maintenance of coal storage areas<br>(2) Inspection of coal shipments<br>(3) Collection and preparation of coal samples<br>(4) Inspection of coal handling equipment | (1.0) |
| c. Given information, explain the procedures used to compute fuel requirements for coal, by correctly answering ~~70% of the~~ 3 out of 4 questions. STS: 15b Meas: PC | (.25/0) |
| d. Using information given, explain the basic facts pertaining to the theory of operation and construction of solid fuel burners, by correctly answering 70% of the questions. STS: 16a(1), 16a(2), 16a(3), 16a(4), 16a(5), 16a(6), 16a(7) Meas: PC<br>(1) Coal burning equipment<br>(2) Theory of operation and construction of solid fuel burners | (1.5/0) |
| e. Using information given, explain the procedures used to remove and install solid fuel burners, perform preoperational checks, operate, adjust, maintain and troubleshoot solid fuel burners, adjust fuel-air ratio and record fuel consumption and type of fuel, by correctly answering ~~70% of the~~ questions. 6 out of 8 STS: 16b, 16c, 16d, 16e, 16f, 16g, 16h, 16i, 16j Meas: PC | (1.25/0) |

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(1) Removal and installation of solid fuel burners

(2) Preoperational checks

(3) Operation, adjustment, maintenance and troubleshooting of solid fuel burners

(4) Adjustment of fuel-air ratio

(5) Recording of fuel consumption

## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-IV-5, Solid Fuel Burners
WB J3ABR54532 001-IV-5, Solid Fuel Burners

Audiovisual Aids
Transparencies, Solid Fuel Burners

Training Equipment
Trainer, Coal Fired Furnace

Training Methods
Lecture/Discussion (4.5 hrs)

Instructional Guidance
Using information extracted from AFM 85-12, explain to the students the different types of coal and their characteristics. Using transparencies, show students how coal is stored, how it is shipped, inspection of coal shipments, and finally how to collect and prepare a coal sample for analysis. Show the students the different types of solid fuel burners, their construction features and operation and how to maintain them. After you have finished discussing this, have the students complete the exercise in the workbook.

Instructor Reference Materials:
AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems

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|---|---|
| 6. Written Test and Test Critique | 1.5 |
| (a) Written Test | (1.0) |
| (b) Test Critique | (0.5) |
| 7. MT: Physical Conditioning (Day 20) | 2 |

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Hot Water Heating Systems and Controls

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 1. Hot Water Heating and Controls | 6/2 |
| a. Using information given, explain the principles of operation of low/medium temperature hot water boilers and their components, by correctly answering 80% of the questions. STS: 13b(1), 21a Meas: PC | (3/2) |
| (1) Principles of operation of hot water boilers | |
| (2) Types of low/medium temperature hot water boilers | |
| (3) Hot water boiler accessories | |
| b. Given procedures and trainer, install, operate and maintain a centrifugal pump with no more than two instructor assists. STS: 13b(2), 13b(3), 13b(4) Meas: PC | (3/0) |
| (1) Installation procedures | |
| (2) Procedures for operating | |
| (3) Procedures for maintaining | |

SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-V-1, Hot Water Heating and Controls
WB J3ABR54532 001-V-1, Hot Water Heating and Controls

Audiovisual Aids
Transparencies, Hot Water Heating Systems

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Training Equipment
Trainer, Hot Water Heating System

Training Methods
Lecture/Discussion (~~6~~ 3.5 hrs)
Directed Study (2 hrs)
Performance (2.5 hrs)

Instructional Guidance
Start first hour of day by taking students to the lab and showing them the low temperature hot water system and explain the principles of operation. Return to the classroom and continue by explaining the different types of hot water boilers. Using transparencies, show and explain the purpose and operation of the pressure relief valve, pressure gauge, temperature gauge and aquastats. Explain the purpose of boiler connections, such as outlet connection, return connection, control valves, blow-off connections, water supply connections and chimney and breechings. Show to the students how water is fed to the boiler through the pressure reducing valve and also how to manually feed water to the boiler. Explain the purpose of the expansion tank, types of expansion tanks, sizing of expansion tanks, location of expansion tanks and components on the expansion tanks. Directed Study assignments for this objective will be given at the end of day 21. Check for completion at the start of day 22.

Instructor Reference Materials:
AFM 85-12, Vols I and II, Operation and Maintenance of Control Heating Plants and Distribution Systems, and Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization
Modern Refrigeration and Air Conditioning Textbook

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Hot Water Heating Systems

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 2. Hot Water Distribution Systems | 3/1 |
| a. Using information given, explain the types of hot water distribution systems and their components by correctly answering 80% of the questions. STS: 21a Meas: PC | (2.5/1) |
| (1) Types of hot water distribution systems | |
| (2) Components of hot water distribution systems | |
| b. Using information given, explain the procedures to follow to install a secondary hot water heating system, by correctly answering ~~80% of the~~ questions. STS: 19r Meas: PC<br>2 out of 3 | (.5/0) |

### SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-V-2, Hot Water Distribution System
WB J3ABR54532 001-V-2, Hot Water Distribution System

Audiovisual Aids
Transparencies, Hot Water Heating Systems

Training Equipment
Trainer, Hot Water Heating System
Assorted Hot Water Boiler Accessories

Training Methods
Lecture/Discussion (3 hrs)
Directed Study (1 hr)

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Instructional Guidance
Have all trainers and equipment available. Using transparencies show to the students the different types of hot water systems such as the forced circulation One-Pipe System, Two-Pipe Directed Return, Two-Pipe Reverse Return, Series-Loop System, and the Combined Systems. Show and explain the purpose and operation of the Special Flow Fittings, Air-Bleed Valve, and other components such as gate valves, globe valves, check valves, plug cocks, anchors, hangers, supports, expansion joints, and strainers. Explain how flow adjustment and balancing are obtained by using pipe size orifices and throttle valves. Explain how temperature is controlled by zoning such as Single-Zone and Multiple-Zone installations. Finish lesson by explaining the different methods used to transfer the generated heat such as radiators, convectors, panel heating and unit heaters.

Instructor Reference Materials:
AFM 85-12, Vols I and II, Operation and Maintenance of Control Heating Plants and Distribution Systems, and Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

**BLOCK TITLE**
Hot Water Heating Systems

| 1. COURSE CONTENT | 2. TIME |
|---|---|

3. Troubleshooting Hot Water Systems 1/1

a. Using information given, explain the proper procedures to follow in troubleshooting a hot water heating system by correctly answering 80% of the questions. STS: 21k(3) Meas: PC (.5/.5)

(1) Procedures used to troubleshoot fireside

(2) Procedures used to troubleshoot waterside

(3) Procedures used to troubleshoot system

b. Using information given, explain how to inspect and replace aquastats, maintenance of pressure regulators, procedures used to inpsect and maintain special flow fittings, installation of air-bleed valves and pressure regulators, procedures used to balance system and inspecting boilers for leaks, corrosion and scale by correctly answering 80% of the questions. STS: 21j, 21k(1), 21k(2), 21k(4), 21k(5), 21k(6), 21k(7), 21k(8), 21k(9), 21k(10) Meas: PC (.5/.5)

(1) Procedures used to inspect and replace aquastats

(2) Pressure regulator maintenance procedures

(3) Inspection and maintenance procedures for special flow fittings

(4) Installation procedures for air-bleed valves and pressure regulators

(5) Procedures used to balance system

(6) Inspecting boilers for leaks, corrosion and scale

SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-V-3, Troubleshooting Hot Water Systems
WB J3ABR54532 001-V-3, Troubleshooting Hot Water Systems

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Audiovisual Aids
Transparencies, Hot Water Heating Systems

Training Equipment
Trainer, Hot Water Heating System

Training Methods
Lecture/Discussion (1 hr)
Directed Study (1 hr)

Instructional Guidance
Have all trainers and equipment available and emphasize safety when working with the trainers. Start lesson by explaining to the students what is meant by fireside, waterside, and systems, then explain the procedures used to troubleshoot each. Continue lesson by explaining how to inspect and replace aquastats, pressure regulators, special flow fittings. Finish lesson by explaining how to install air-bleed valves and pressure regulators and finally the procedures used to balance system and inspect boiler for leaks, corrosion and scale.

Instructor Reference Materials:
AFM 85-12, Vols I and II, Operation and Maintenance of Control Heating Plants and Distribution Systems, and Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization
Modern Refrigeration and Air Conditioning Textbook

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Hot Water Heating Systems

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 4. Operation and Maintenance of Hot Water Systems | 6/1 |
| a. ~~Using information given~~ Given Procedures, remove a boiler from service, drain, flush and fill boiler ~~with instructor assistan~~ce. STS: ~~13b(2)~~, ~~13b(3)~~, ~~13b(4)~~ 21b, 21c, 21d, 21e, 21f, 21g, 21h, 21i Meas: PC and check boiler For proper Operation with instructor assistance. | (3/1) |
| (1) Procedures for removing a boiler from service | |
| (2) Procedures for draining boiler | |
| (3) Procedures for flushing boiler | |
| (4) Procedures for filling boiler | |
| (5) Procedures for charging expansion tank | |
| (6) Preoperational inspection procedures | |
| (7) Procedures to properly fire boiler | |
| b. Using information given, inspect boiler for leaks, inspect and replace aquastats and maintain pressure regulators with instructor assistance. STS: 3e(2), 3e(9), 21k(2), 21k(5), 21k(6), 21k(7) Meas: PC | (2/0) |
| (1) Procedures used to inspect boiler for leaks | |
| (2) Aquastat inspection procedures | |
| (3) Replacement procedures for aquastat | |
| (4) Procedures used to maintain pressure regulators | |
| c. Using information given, inspect for corrosion and scale and troubleshoot hot water heating system with instructor assistance. STS: 3e(2), 3e(10), 21k(3), 21k(10) Meas: PC | (1/0) |
| (1) Procedures used in inspecting for corrosion and scale | |
| (2) Troubleshooting procedures | |

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## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-V-4, Operation and Maintenance of Hot Water Systems
WB J3ABR54532 001-V-4, Operation and Maintenance of Hot Water Systems

Audiovisual Aids
Transparencies, Hot Water Heating Systems

Training Equipment
Trainer, Hot Water Heating System

Training Methods
Lecture/Discussion (2 hrs)
Demonstration (.5 hrs)
Performance (3.5 hrs)
Directed Study (1 hrs)

Instructional Guidance
Have all equipment and tools available and emphasize safety when working with the trainers. Start day by giving overview of all material covered pertaining to hydronics such as operation of boilers and their components, procedures used to remove a boiler from service, draining, flushing, filling boiler, charging expansion tank, performance of a preoperational inspection, firing boiler, inspecting and replacing aquastats, maintenance of pressure regulators, special flow fittings, air-bleed valves, inspecting for leaks, corrosion and scale, balancing system and finally how to troublshoot system. After you have completed this, take the students to the lab and demonstrate to them how to do all the above. Once you have completed this, have the students, working as a team, perform a complete breakdown of the boiler and system. This should include securing boiler, draining boiler and system, opening boiler up and inspecting for corrosion, scale and any other possible problems. Have them drain and flush the expansion tank, remove and clean gauge glass on tank, open all valves throughout system and flush entire system with fresh water until water is clear. Once system has been thoroughly cleaned out, put boiler and system back together. Check all valves, including pressure relief and flow control valves, for leaks or other possible defects. Once this has been completed put boiler and its components back together and fill boiler and system. Be sure to have students properly charge expansion tank before filling. Perform a preoperational inspection. If everything is OK, have students fire up boiler. During fire-up have students troubleshoot boiler and system to assure trouble free operation.

Instructor Reference Materials:
AFM 85-12, Vols I and II, Operation and Maintenance of Control Heating Plants and Distribution Systems, and Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Hot Water Heating Systems

| 1. COURSE CONTENT | 2. TIME |
|---|---|

5. Soldering and Welding 12.5/3

a. Given information, explain basic facts about the types and sizes of copper tubing and fittings by correctly answering 80% of the questions. STS: 10c(1), 10c(2) Meas: PC (1/1)

(1) Copper tubing

(2) Fittings

b. Given hand tools, copper tubing kit, copper tubing and instructions, measure, cut, bend, swage, and flare the copper tubing with a maximum of two instructor assists. STS: 10c(3), 10c(4), 10c(5), 10c(6), 10c(7) Meas: PC (3.0/.5)

(1) Measuring procedures

(2) Cutting procedures

(3) Bending procedures

(4) Swaging procedures

(5) Flaring procedures

c. Given hand tools, sandpaper, steel wool, hydrocarbon torch and assortment of fittings, use proper techniques to soft solder two copper tubing joints with a maximum of two instructor assists. STS: 10c(8), 11a Meas: PC (2/.5)

(1) Fabricating copper tubing system

(2) Proper techniques for soft soldering

d. Given information, identify the theory of oxyacetylene welding and related equipment by answering 80% of the questions. STS: 11b Meas: PC (1.0/.5)

(1) Oxyacetylene combustion

(2) Types of flames

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(3) Oxyacetylene equipment

(4) Safety precautions when using oxyacetylene equipment

(5) Types of solder

e. Given hand tools, copper tubing, oxyacetylene equipment, silphos and flux, use proper techniques to hard solder two copper tubing joints with a maximum of two instructor assists. STS: 11c(1) Meas: PC (2.0/.5)

(1) Procedures for hard soldering

(2) Safety precautions when using oxyacetylene equipment

f. Given hand tools, metal, oxyacetylene equipment, and sandpaper, use proper techniques to weld two pieces of metal together with at least 80% weld penetration with a maximum of two instructor assists. STS: 11c(2) Meas: PC (3.5)

(1) Procedures for welding

(2) Safety precautions

## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-V-5, Soldering and Welding
WB J3ABR54532 001-V-5, Soldering and Welding

Audiovisual Aids
Transparencies

Training Equipment
Hand tools
Sandpaper
Steel wool
Copper tubing kit
Copper tubing
Hydrocarbon torch kit
Assortment of fittings
Oxyacetylene equipment
Silphos
Flux

Training Methods
Lecture/Discussion (3.0 hrs)
Demonstration (1.0 hr)
Performance (8.5 hrs)
Directed Study (3 hrs)

Instructional Guidance
Day 23 - Discuss types and sizes of copper tubing and fittings. Explain measuring and cutting procedures for copper tubing.
Day 24 - Check directed Study Assignment. Discuss bending, swaging and flaring procedures. Demonstrate measuring, cutting, bending, swaging and flaring procedures. Observe students as they perform measuring, cutting, bending, swaging and flaring procedures on copper tubing. Discuss and demonstrate soft soldering procedures. Have students perform soft soldering procedures on copper tubing joints that they prepared. Explain and discuss theory of oxyacetylene welding. Discuss hard soldering procedures and demonstrate. Have students perform hard soldering procedures on copper tubing joints they prepared. Emphasize proper safety precautions when using oxyacetylene equipment. Discuss and demonstrate oxyacetylene welding procedures. Observe students as they perform oxyacetylene welding. Day 25 will be a continuance of this performance.

Instructor Reference Materials:
Textbook, Modern Refrigeration and Air Conditioning
TO 34W-4-1-5, Welding Theory and Application
Textbook, Modern Welding

| | |
|---|---|
| 6. Written Test and Test Critique | 1.5 |
| a. Written Test | (1.0) |
| b. Test Critique | (0.5) |
| 7. MT: Physical Conditioning (Day 25) | 2 |

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Central Plant and High Temperature Water Heating Systems

| 1. COURSE CONTENT | 2. TIME |
|---|---|

1. Theory of Operation and Construction of Steam Heating Systems — 12/4

a. Given information, identify principles concerning theory of operation and construction features of steam heating systems, with 70% accuracy. STS: 24a Meas: PC — (6/1)

(1) Central heating plants

(2) Fundamentals of steam generation

(3) Boiler construction features

(4) Types of boilers

(5) ASME Code for external fittings

b. Given information, identify the procedures for removing and installing boilers, ~~with 70% accuracy.~~ by correctly identifying 10 out of 14 components. , STS: 19l, 19m Meas: PC — (.5/0)

(1) Manufacturer's specifications

(2) ASME

c. Given information, identify basic facts about components of feedwater system, with 70% accuracy. STS: 24g, 13a(1) Meas: PC — (.5/1)

(1) Theory and construction of steam turbines

(2) Theory and construction of reciprocating pumps

(3) Theory and construction of feedwater systems

d. Given information, determine procedures for installation, operation and maintenance of reciprocating pumps, with 80% accuracy. STS: 13a(2), 13a(3), 13a(4) Meas: PC — (0/.5)

(1) Installation of reciprocating pumps

(2) Operation of reciprocating pumps

(3) Servicing of reciprocating pumps

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## COURSE CONTENT

e. Given information, determine step-by-step procedures for operating and servicing pressure/temperature recording equipment, with 80% accuracy. STS: 14a, 14b, 14c Meas: PC (1/.5)

(1) Pressure controls

(2) Air flow switch

(3) Draft controls

(4) Operation of pressure/temperature recording equipment

(5) Servicing of pressure/temperature recording equipment

f. Given information, operate and service draft indicating and regulating equipment, with instructor assistance. STS: 14c, 14e Meas: PC (0.5)

g. Given information, perform service of flow meters and recorders, with instructor assistance. STS: 14g Meas: PC (0.5)

h. Given information, troubleshoot boiler flame control system, with instructor assistance. STS: 9a(9) Meas: PC (3.0/1)
9a(8)

## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-VI-1, Theory of Operation and Construction of Steam Heating Systems
WB J3ABR54532 001-VI-1, Theory of Operation and Construction of Steam Heating Systems

Audiovisual Aids
Transparencies, Central Heating Plants

Training Equipment
Trainer, High Pressure and Low Pressure Boiler and Systems
Trainer, Steam and Water Cycle
Trainer, Feedwater System
Trainer, Reciprocating Pump
Trainer, Steam Flow, Air Flow Recorder
Trainer, Pressure Control
Trainer, Programmer Tester

Training Methods
Lecture/Discussion (9 hrs)
Performance (3 hrs)
Directed Study (4 hrs)

Instructional Guidance

Discuss the types of Central Plants and the fundamentals of steam generation. Using transparencies, discuss boiler construction features, types of boilers and ASME code pertaining to external boiler fittings. Give students directed study assignment and boiler construction features, steam turbines and reciprocating pumps, Exercises 1, 4 and 5 of workbook, at the end of day 26. Give students quiz at beginning of day 27 on directed study assignment. Discuss procedures for removing and installing boilers. Take students to heating lab, using high pressure boiler, have students complete Exercises 2 and 3 in workbook. Return students to classroom after completion. Using transparencies and cut-aways, discuss the theory and construction of the feedwater system. Discuss the procedures for operating and servicing of pressure/temperature recording equipment. Using transparencies discuss operation and servicing of draft indicating and regulating equipment. Discuss Flow Meters and Recorders. Discuss boiler Flame Control System. Take students to heat lab and have students complete exercises 8 and 9 in workbook. Have students return to classroom and compelte exercise 10 in workbook. Give students directed study assignment on Installation, Maintenance and Operation of Reciprocating Pumps, Exercise 6, on Pressure/Temperature Recording Equipment, Exercise 7, and boiler Flame Control System, Exercise 11 at the end of day 27. Give quiz over directed study at beginning of day 28.

Instructor Reference Materials:
AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants
NTTC Course 135, Energy Conservation Through Utilities Operation
NAVFAC Tech Tng Center, Navy Public Works Center, Norfolk VA 23511

PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
|  | Heating Systems Specialist |

BLOCK TITLE
Central Plant and High Temperature Water Heating Systems

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 2. Boiler Operations | 10/4 |
| a. Given information, operate a steam boiler, with instructor assistance. STS: 3e(3), 3e(8), 24b, 24e(1), 24e(2), 24e(3), 24e(4), 24e(5), 24e(6), 24e(7), 24e(8) Meas: PC | (9/3) |
| (1) Safety for high intensity sound<br>(2) Steam safety<br>(3) Preoperational inspection<br>(4) Operation of draft control<br>(5) Operation of air flow switch<br>(6) Firing procedures<br>(7) Proper water level<br>(8) Blow off procedures<br>(9) Operation of pressure control<br>(10) Emergency procedures<br>(11) Shut down procedures |  |
| b. Given information, determine step-by-step procedures for operating and maintaining oil preheaters, ~~with 70% accuracy.~~ by Correctly STS: 24e(10), 24e(11) Meas: PC - answering 4 out of 5 questions. | (0/1) |
| (1) Operating procedures<br>(2) Maintaining procedures |  |
| c. Given simulated job type entries, complete steam logs and fuel consumption report, with instructor assistance. STS: 17b, 24e(9) Meas: PC | (1/0) |

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(1) AF Form 1458

(2) AF Form 1464

## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-VI-2, Boiler Operations
WB J3ABR54532 001-VI-2, Boiler Operations

Audiovisual Aids
Transparencies, Central Heating Plants, Logs

Training Equipment
Trainer, High Pressure and Low Pressure Boilers

Training Methods
Lecture/Discussion (1 hr)
Demonstration (.5 hr)
Performance (8.5 hrs)
Directed Study (4 hrs)

Instructional Guidance
Discuss procedures for operating steam boiler to include the following items: Safety for high intensity sound, safety around steam, preoperational inspection and operation of draft control and air flow switch. Discuss firing procedures and maintaining proper water level. Discuss how to check operation of pressure control. Discuss emergency procedures for common boiler emergencies. Discuss boiler shutdown procedures. Take students to heating lab and demonstrate how to operate steam boiler. Have students operate steam boiler using procedures in Exercise 2 in workbook. Have students maintain proper water level using Exercise 1 in workbook. Have students check operation of pressure control using low pressure boiler. At end of Day 28 assign directed study assignment using Exercise 3 in workbook. Check directed study assignment at beginning of Day 29. Finish operating steam boiler (Day 29), return students to classroom and hand out daily and monthly steam Operating Logs. Have students complete logs. Give Directed Study assignment for Day 29, Exercise 4 and 5 of workbook.

Instructor Reference Materials:
AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants

# PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
|  | Heating Systems Specialist |

BLOCK TITLE
Central Plant and High Temperature Water Heating Systems

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 3. High Temperature Water Heating Systems | 6.5/0 |
| a. Given information, identify the methods of producing high temperature water, with 70% accuracy. STS: 23a, 23b, 23c, 23d Meas: PC | (2/0) |
| (1) Theory of operation<br>(2) Methods of producing HTW<br>(3) HTW plant auxiliary equipment<br>(4) Safety principles |  |
| b. Following step-by-step procedures, operate and maintain the high temperature hot water heating system trainer and distribution system, with instructor assistance. STS: 23e(1), 23e(2), 23e(3), 23e(4), 23e(5), 23f(1), 23f(2), 23f(3), 23f(4), 23f(8), 23i Meas: PC | (3.5/0) |
| (1) Valve alignment<br>(2) Required water flow<br>(3) Safety controls<br>(4) Starting procedures<br>(5) Operational checks<br>(6) Distribution system<br>(7) Air bleeding procedures<br>(8) Procedures for adjusting control devices and regulating valves<br>(9) Operation of secondary systems<br>(10) Operating logs |  |
| c. Using information maintain a pumping system, with instructor assistance. STS: 23g, 23h Meas: PC | (.5/0) |

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(1) Pressurization system

(2) Pumping system

d. Given information list the procedures for performing hydrostatic test on generator and expansion drum, with 70% accuracy. STS: 23j, 23k Meas: PC (.5/0)

(1) Types of inspections

(2) Hydrostatic test procedures

## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-VI-3, High Temperature Water Heating Systems
WB J3ABR54532 001-VI-3, High Temperature Water Heating Systems

Audiovisual Aids
Transparencies, HTW Systems

Training Equipment
Trainer, High Temperature Hot Water

Training Methods
Lecture/Discussion (3 hrs)
Demonstration (.5 hr)
Performance (3.0 hrs)

Instructional Guidance
Discuss types of HTW generators major components, methods of pressurization, types of auxiliary equipment and types of pumping systems. Instructor start up HTW system and shut down. Class then start up HTW system and secure it, with instructor assistance, following workbook exercise.

Instructor Reference Materials:
AFR 88-28, High Temperature Water Heating Systems

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| 4. Written Test and Test Critique | 1.5 hrs |
| (a) Written Test | (1.0 hr) |
| (b) Test Critique | (.5 hr) |
| 5. MT: Physical Conditioning (Day 30) | 2 |

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
|  | Heating Systems Specialist |

BLOCK TITLE
Boiler Maintenance and Steam Distribution Systems

1. COURSE CONTENT — 2. TIME

1. External Boiler Maintenance 8/2

a. Given proper procedures and with team member, replace and test safety valve, with instructor assistance. STS: 3e(10), 24c(1), 24c(2) Meas: PC (1.5/0)

(1) Procedures for replacing safety valve

(2) Procedures for testing safety valve

(3) Safety precautions when using air pressure

b. Given instructions and with team member, replace gage, with instructor assistance. STS: 14f Meas: PC (1/0)

c. Following given procedures and with team member, clean water column and gage glass, with instructor assistance. STS: 24c(3) Meas: PC (1.5/0)

(1) Procedures for cleaning water column

(2) Procedures for cleaning gage glass

d. Using information, answer questions about inspection and replacement of soft plugs to 80% accuracy. STS: 24c(4), 24c(5) Meas: PC (.5/.5)

(1) Procedures for inspection of soft plug

(2) Procedures for replacement of soft plug

e. Given procedures check and clean boiler fireside, with instructor assistance. STS: 24d(6), 24d(7) Meas: PC (1.5/0)

(1) Procedures for checking fireside

(2) Procedures for cleaning fireside

f. Given procedures and working with team member, repair and replace refractory, with instructor assistance. STS: 19p, 19q Meas: PC (2/1.5)

(1) Types of refractory material

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(2) Minor refractory repair

(3) Procedures for replacing refractory material

## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-VII-1, External Boiler Maintenance
WB J3ABR54532 001-VII-1, External Boiler Maintenance

Audiovisual Aids
Transparencies, Fireside Maintenance
7862A Fireside Movie
7862B Fireside Movie

Training Equipment
Trainer, High Pressure Boiler, Firebox Boiler, Low Pressure Boiler (if needed)
Trainer, Water Column and Sight Glass

Training Methods
Lecture/Discussion (1 hr)
Demonstration (.25 hr)
Performance (6.75 hrs)
Directed Study (2.0 hrs)

Instructional Guidance
Discuss the procedures for replacing safety valve, discuss procedures for testing safety valves. Discuss how to clean gage glass and water column. Ask questions about inspection and replacement of soft plug. Discuss procedures for checking fireside and cleaning fireside. Discuss types of refractory material, minor refractory repair and the procedures for replacing refractory material. Show movies on fireside replacement. Give directed study assignment, Exercises 4 and 6. Check students' Directed Study assignment at beginning of day 32. Take students to heating lab, making sure that safety is emphasized and that students have removed jewelry. Take students to safety valve trainer, have them replace safety valve and test replacement safety valve. Take students to high pressure boiler, have students remove, clean and reinstall gage glass. Have students tear down water column and clean, replacing any defective or worn parts, reassemble water column. Take students to backside of high pressure boiler, remove back and check fireside for cleanliness, then have students clean fireside or high pressure boilers. Take students to firebox boilers behind heating lab building and have students remove refractory material from firebox boilers, then reinstall refractory material. Have students clean up area around firebox boilers and around high pressure boiler. Have students return to classroom in an orderly manner. Low pressure boiler may be used for accomplishment of criterions if high pressure boiler is not available.

Instructor Reference Materials:
AFM 85-12, Vol I

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| | |
|---|---|
| NAME OF INSTRUCTOR | COURSE TITLE<br>Heating Systems Specialist |

BLOCK TITLE
Boiler Maintenance and Steam Distribution Systems

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 2. Internal Boiler Maintenance | 7/2.5 |
| a. Given proper procedures and with team member, maintain boiler water side components, with instructor assistance. STS: 24c(6), 24d(1), 24d(3), 24d(4), 24d(5), 24d(8), 24d(9), 24d(10) Meas: PC | (4.75 1.0) |
| (1) Procedures for preparing boiler for inspection | |
| (2) Safety precautions | |
| (3) Procedures for draining boiler | |
| (4) Procedures for cleaning tubes | |
| (5) Procedures for washing down boiler interior | |
| (6) Inspection of water side | |
| (7) Procedures for replacing manhole and handhole covered gaskets | |
| (8) Procedures to fill boiler | |
| (9) Inspection for leaks | |
| b. Given information and with team member, inspect for internal corrosion, with instructor assistance. STS: 24d(2) Meas: PC | (.25/ .5) |
| (1) Types of corrosion | |
| (2) Inspection procedures | |
| c. Following step-by-step procedures and with team member, perform a hydrostatic test, with instructor assistance. STS: 24d(11) Meas: PC | (1/1) |
| (1) Types of hydrostatic tests | |
| (2) Protection of pressure controls | |
| (3) Procedures for securing safety valve | |

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(4) Closing of valves

(5) Filling procedures

(6) Procedures for performing hydrostatic test

d. Given information and with team member and following step-by-step procedures, make minor tube repair, with instructor assistance. (1/0)
STS: 24d(12) Meas: PC

(1) Types of minor tube repair

(2) Plugging a boiler tube

## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-VII-2, Internal Boiler Maintenance
WB J3ABR54532 001-VII-2, Internal Boiler Maintenance

Audiovisual Aids
Transparencies
Film

Training Equipment
Trainer, High Pressure Boiler
Trainer, Low Pressure Boiler (if needed)
Trainer, Firebox Boiler

Training Methods
Lecture/Discussion (1.5 hrs)
Demonstration (.5 hr)
Performance (5 hrs)
Directed Study (2.5 hrs)

Instructional Guidance

Using study guide and transparencies, discuss procedures for shutting down boiler in service. Discuss procedures for internal maintenance on boilers to include safety precautions, draining boiler, cleaning boiler tubes, washing down interior of boiler, inspection of waterside, procedures for replacing handhole and manhole cover gaskets, procedures to fill boiler and check for leaks. Discuss what to look for while performing inspection for internal corrosion. Discuss procedures for performing hydrostatic test on boilers, also to include the types of hydrostatic tests. Using transparencies, discuss minor tube repair and how to plug a tube. Take students to heating lab, have students work in teams. Make sure students remove all jewelry. Have students drain high pressure boiler (use low pressure boiler if necessary), remove handholes, wash down interior of boiler. Have students clean handholes, plugs and inspect for internal corrosion. Have students replace handholes, then fill boiler with water. Have students prepare boiler for hydrostatic test, then perform hydrostatic test, checking for leaks. After hydrostatic test, return boiler water level to proper limits. Have students clean up area around high pressure boiler. Take students out to firebox boilers and working as team members, have students plug a fire tube in firebox boiler. Have students clean up area around firebox boilers. Direct students back to classroom in an orderly manner.

Instructor Reference Materials:

AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems

AFM 85-12, Vol II, Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization

## PLAN OF INSTRUCTION/LESSON PLAN PART I

NAME OF INSTRUCTOR

COURSE TITLE
Heating Systems Specialist

BLOCK TITLE
Boiler Maintenance and Steam Distribution Systems

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 3. Boiler Lay Up | .5/.5 |

3. Boiler Lay Up

a. Given information answer questions about boiler lay up, with 80% accuracy. STS: 24d(13)(a), 24d(13)(b) Meas: PC

(1) Wet method

(2) Dry method

### SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-VII-3, Boiler Lay Up
WB J3ABR54532 001-VII-3, Boiler Lay Up

Audiovisual Aids
Transparencies on Boiler Lay Up

Training Equipment
Silica Gel

Training Methods
Lecture/Discussion (.5 hr)
Directed Study (.5 hr)

Instructional Guidance
Using transparencies, discuss the procedures for laying up boiler using the wet method and procedures for the dry method. Have students complete workbook exercises in class. Instructor will check workbook.

Instructor Reference Material:
AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems

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| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Boiler Maintenance and Steam Distribution Systems

| 1. COURSE CONTENT | 2. TIME |
|---|---|

4. Steam Distribution Systems 13/3

a. Given information and with team member maintain steam pressure using steam distribution system, with instructor assistance. (4/.5)
STS: 24f(1), 24f(2), 24f(3), 24f(9) Meas: PC

(1) Lining up steam system

(2) Lining up pressure reducing station

(3) Temperature regulating valve

(4) Expansion joints

b. Given information answer questions about distribution system and conduits, getting 80% of questions correct. (.5/.5)
STS: 23f(5), 23f(6), 23f(7), 24f(10), 24f(13) Meas: PC

(1) Types of steam line conduits

(2) Inspection of steam line conduits

(3) Inspection of manholes

c. Given information answer questions about installation and maintenance of converters, getting 80% of questions correct. (.5/.5)
STS: 24f(11), 24f(12) Meas: PC

(1) Procedures for installation of converters

(2) Procedures for maintenance of converters

d. Given procedures and with team member, perform maintenance on steam distribution system, with instructor assistance. STS: 24f(4), 24f(5), 24f(6), 24f(7), 24f(8) Meas: PC (4.5/1)

(1) Inspection of traps

(2) Procedures to repair traps

(3) Procedures to replace traps

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(4) Procedures for cleaning strainers

(5) Procedures for replacing strainers

(6) Condensate return system

e. Given procedures and with team member, replace insulation on steam distribution system, with instructor assistance. (3.5/.5)
STS: 24f(14)(a), 24f(14)(b), 24f(14)(c) Meas: PC

(1) Types of insulation

(2) Procedures for mixing insulation

(3) Procedures for applying insulation

(4) Procedures for applying pre-formed insulation

## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-VII-4, Steam Distribution Systems
WB J3ABR54532 001-VII-4, Steam Distribution Systems

Audiovisual Aids
Transparencies, Steam Distribution Systems

Training Equipment
Steam Distribution Systems

Training Methods
Lecture/Discussion (3.5 hrs)
Performance (9.5 hrs)
Directed Study (3 hrs)

Instructional Guidance
Using transparencies, discuss line up of steam distribution system, to include pressure reducing station comprising of the parts to a pressure reducing station. Discuss the function and maintenance of a temperature regulating valve. Discuss types of expansion joints and maintenance procedures. Check workbook exercise on steam line conduits according to lesson plan. Check workbook exercise on converters according to lesson plan. Using transparencies, discuss maintenance procedures on steam distribution system to include inspection of traps, repair of traps, replacement of traps, cleaning strainers, replacing strainers. Discuss different types of condensate return systems. Discuss types of insulation, procedures for mixing insulation, procedures for applying insulation, and procedures for applying preformed insulation. Take students out to heating lab in an orderly manner, have students remove all jewelry. Have students trace steam distribution system and pressure reducing station. Have students check out expansion joints and lubricate if needed. While steam system is in operation have students inspect traps for leaks and proper operation. Shut down steam system and have students, working as a two-man team (if class size dictates), remove traps and strainers from system, remove all existing insulation. Clean traps and strainers and repair or replace any defective parts. If needed, replace either part completely out. Reinstall traps and strainers to proper place on steam system, reopen steam system, have students check traps for leaks and proper operation. Have students prepare for insulation criterion by mixing powdered insulation and wheat paste mixture. Show students how to apply powdered insulation and cheesecloth. Show students how to apply preformed insulation. Have students apply powdered insulation, then apply pre-formed insulation. After students have completed criterion, have students clean area around steam distribution system to include mopping. Make sure students also clean up around workbench area after trap and strainer criterion is completed. Have students return to class in an orderly manner and get ready to take block test.

Instructor Reference Materials:
AFM 85-12, Vols I and II

| | |
|---|---|
| 5. Written Test and Test Critique | 1.5 |
| (a) Written Test | (1.0) |
| (b) Test Critique | (0.5) |
| 6. MT: Physical Conditioning (Day 35) | 2 |

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
|  | Heating Systems Specialist |

BLOCK TITLE
Boiler Water Treatment and External Corrosion

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 1. Sources of Water | 3/0 |

a. Given information, explain basic facts about sources of water and their characteristics with 80% accuracy. STS: 25a, 25b
Meas: PC

(1) Sources of water

(2) Characteristics of water

(3) pH of water

(4) Major contributors to corrosion

SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-VIII-1, Sources of Water
WB J3ABR54532 001-VIII-1, Sources of Water

Audiovisual Aids
Transparencies, Water: Sources, Characteristics, and Effects on Heating Equipment

Training Methods
Lecture/Discussion (2.5 hrs)
Demonstration (.5 hr)

Instructional Guidance
Using Terms and Definitions Glossary in Student Study Guide, discuss the terms as they apply to water treatment. Emphasize the relationship for those terms that relate. Using transparencies, discuss surface and ground water characteristics and what impurities they each contain. Discuss the objectives of boiler water treatment. Using raw sample, a pH test kit, litmus paper, and pH meter, a 20-ml bottle of caustic soda, and a 20-ml bottle of HCL-3N (diluted acid), discuss the pH scale and effective pH range for effective boiler water treatment. Discuss the major contributors to corrosion and their effects.

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Instructor Reference Materials:
AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems
AFM 85-13, Industrial Water Treatment

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Boiler Water Treatment and External Corrosion

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 2. External Treatment | 7/2 |
| a. Given information, determine step-by-step procedures for installation, operation, and servicing of external water treatment equipment, with 80% accuracy. STS: 25p, 25s, 25t, 25u<br>Meas: PC | (3.5/ .5) |
| (1) Demineralizing equipment | |
| (2) Degasification equipment | |
| (3) Direct acid treatment | |
| b. Given information and equipment, service and operate demineralizing equipment, with instructor assistance. STS: 25q, 25r<br>Meas: PC | (2/.5) |
| (1) Operating demineralizing equipment | |
| (2) Servicing demineralizing equipment | |
| c. Using the soap solution and EDTA water testing equipment, test a given water sample for hardness, with instructor assistance.<br>STS: 25e Meas: PC | (1.5/1) |
| (1) Soap solution test | |
| (2) EDTA solution test | |

### SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-VIII-2, External Treatment
WB J3ABR54532 001-VIII-2, External Treatment

Audiovisual Aids
Transparencies, External Boiler Water Treatment

Training Equipment
Trainer, Water Softener
Soap Solution and EDTA Water Testing Equipment

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Training Methods
Lecture/Discussion (2.5 hrs)
Demonstration (1.5 hrs)
Performance (3 hrs)
Directed Study (2 hrs)

Instructional Guidance
Using transparencies as needed, discuss the different means of removing suspended and dissolved impurities. Discuss the different types of degasification equipment and their uses. Discuss the different water hardness tests, then demonstrate procedures. Demonstrate a complete cycle of the water softener trainer with students. Then have students operate and inspect the softener for proper operation by performing a water hardness test.

Instructor Reference Materials:
AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems
AFM 85-13, Industrial Water Treatment

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
|  | Heating Systems Specialist |

BLOCK TITLE

Boiler Water Treatment and External Corrosion

1. COURSE CONTENT — 2. TIME

3. Internal Treatment 10/4

a. Given information, identify principles relating to internal boiler water treatment, with 80% accuracy. STS: 25c Meas: PC (1/1)

(1) Objectives of internal boiler water treatment

(2) Factors affecting internal boiler water treatment

(3) Types of internal boiler water treatment chemicals

b. Given information, select, care and use precision measuring instruments, with instructor assistance. STS: 7g, 7h, 7i Meas: PC (1/0)

(1) pH meter

(2) Electrical conductivity meter

c. Following step-by-step procedures, draw water sample and determine chemical concentrations in a steam boiler, with instructor assistance. STS: 3e(5), 3e(6), 25d, 25g, 25f(1), 25f(2), 25f(3), 25f(4), 25f(5), 25f(6) Meas: PC (6/1)

(1) Procedures for drawing water samples

(2) Inspection of chemical reagents and text equipment

(3) Causticity test

(4) Tannin test

(5) Phosphate test

(6) Sodium sulfite test

(7) Total dissolved solids test

(8) pH test

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d. Given information, explain basic facts pertaining to condensate return treatment, with 80% accuracy. STS: 25h Meas: PC (1/0)

(1) Types of return line corrosion

(2) Causes of return line corrosion

e. Given step-by-step procedures, test and treat condensate return water, with instructor assistance. STS: 25i, 25j Meas: PC (1.1)

(1) Testing condensate water

(1) Treating condensate water

## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-VIII-3, Internal Treatment
WB J3ABR54532 001-VIII-3, Internal Treatment

Audiovisual Aids
Transparencies, Internal Boiler Water Treatment

Training Equipment
Boiler Water Testing Equipment
High Pressure Sample Bottle and Container
High Pressure Steam Boiler
Lab, Boiler Water Treatment

Training Methods
Lecture/Discussion (3.25 hrs)
Demonstration (.5 hr)
Performance (6.25 hrs)
Directed Study (4 hrs)

Instructional Guidance
Using transparencies, discuss objectives of internal boiler water treatment, factors affecting internal boiler water treatment, and types of internal boiler water treatment chemicals, and the reason that each chemical is used and the concentration level for each chemical. Discuss the selection, care, and use of precision measuring instruments. Discuss sampling procedures, procedure for maintaining chemical reagents, test equipment. Emphasize safety while performing all tests. Direct students to boiler area with their sample bottle to draw a boiler water sample following instructions previously learned. Return to lab area; have students don rubber apron and prepare test equipment for testing boiler water. Instruct students to follow step-by-step procedures as outlined in AFM 85-12, Vol I. Instruct students to perform the tests in an orderly fashion. Observe students at all times, answer questions, give explanations, and assist students as necessary; inform students of key steps or particulars to look for, such as color changes, formation of floc, exact measurements and cleanliness. After all tests are completed, have students clean all testing equipment with lab soap and water and put all testing equipment back in the proper places. Have students clean and wax lab table. Have students put away high pressure sample bottles and return to seats. Using transparencies, discuss condensate return water treatment, the causes, testing of condensate return water, and the treatment of condensate return water.

Instructor Reference Materials:
AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems
AFM 85-13, Industrial Water Treatment

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Boiler Water Treatment and External Corrosion

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 4. Logs and Chemical Feeding | 5/2 |
| a. Following step-by-step procedures, maintain water treatment log, with 80% accuracy. STS: 25v Meas: PC | (1/0) |
| (1) Purpose of logs | |
| (2) Annotation of logs | |
| b. Given information and equipment, prepare boiler water sample for shipment, with instructor assistance. STS: 25w Meas: PC | (.5) |
| (1) Boiler classification | |
| (2) Types of containers | |
| (3) Preparation of sample | |
| c. Given information and chemical formulas, compute chemical requirements, with instructor assistance. STS: 25k Meas: PC | (1/1) |
| (1) Formula for sodium sulfite | |
| (2) Formula for caustic soda | |
| (3) Formula for phosphate | |
| (4) Formula for tannin | |
| (5) Formula for amines | |
| d. Given information, determine step-by-step procedures for installation and servicing of chemical feeding equipment, with 80% accuracy. STS: 25m, 25n Meas: PC | (.5/.5) |
| (1) Types of chemical feeders | |
| (2) Installation of chemical feeding equipment | |
| (3) Servicing chemical feeding equipment | |

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e. Using step-by-step procedures, service chemical storage area, with instructor assistance. STS: 25o Meas: PC (1.0)

(1) Safety

(2) Location

(3) Methods

f. Using step-by-step procedures, perform chemical feeding, with instructor assistance. STS: 3e(2), 251 Meas: PC (1/.5)

(1) Protective equipment

(2) Mixing chemicals

(3) Chemical feeding procedures

## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-VIII-4, Logs and Chemical Feeding
WB J3ABR54532 001-VIII-4, Logs and Chemical Feeding

Audiovisual Aids
Transparencies, Water Treatment Logs and Chemical Feeding
AF Form 1459, Monthly Water Treatment Log

Training Methods
Lecture/Discussion (2 hrs)
Demonstration (.5 hr)
Performance (2.5 hrs)
Directed Study (2 hrs)

Instructional Guidance

Give students AF Form 1459; discuss instructions on reverse side, and have each student annotate this log using results of previous boiler water analysis. Discuss the procedures for submitting a boiler water sample for high and/or low pressure boilers. Discuss chemical dosage requirements for boilers under different conditions. (Initial dosage, when blow-downs are required, make up rates and their effect, leaks, and normal daily usage.) Using information on computing chemical dosage required to treat boilers, determine chemicals required to treat the boiler from which samples were taken. Discuss types of chemical feeders, installation and servicing of chemical feeders. Discuss chemical storage area and feeding chemicals. Take students out to boiler area and have students check chemical storage area, don protective equipment, and feed chemicals to boiler.

Instructor Reference Materials:
AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems
AFM 85-13, Industrial Water Treatment

## PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Boiler Water Treatment and External Corrosion

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 5. External Corrosion | 3/0 |
| a. Given information, identify basic facts about external corrosion, with 70% accuracy. STS: 26a(1), 26a(2)(a), 26a(2)(b), 26a(2)(c) Meas: PC | (2/0) |
| (1) Causes of corrosion | |
| (2) Methods of controlling corrosion | |
| (a) Claddings and coatings | |
| (b) Sacrificial anodes | |
| (c) Impressed current | |
| b. Given information, make visual inspection and identify external corrosion, with instructor assistance. STS: 26b Meas: PC | (1/0) |

SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SG J3ABR54532 001-VIII-5, External Corrosion
WB J3ABR54532 001-VIII-5, External Corrosion

Audiovisual Aids
Transparencies, External Corrosion Control
Training Film: TF28031, Soil Corrosion of Pipelines, Part I, Fundamentals
Training Film: TF28032, Soil Corrosion of Pipelines, Part II, Protective Coatings
Training Film: TF28033, Soil Corrosion of Pipelines, Part III, Cathodic Protection with Galvanic Anodes
Training Film: TF28034, Soil Corrosion of Pipelines, Part IV, Cathodic Protection With Impressed Current

Training Methods
Lecture/Discussion (2 hrs)
Performance (1 hr)

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Instructional Guidance

Using transparencies, discuss the effects of external corrosion on heating systems and bring out the causes of external corrosion and the proper method of treating external corrosion. Show the training film on cathodic protection and point out the highlights for the students to look for while watching the film. Stress personnel and equipment safety at all times.

Instructor Reference Materials:
AFR 85-5, Maintenance and Operation of Cathodic Protection Systems
AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems

## PLAN OF INSTRUCTION/LESSON PLAN PART I

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|---|---|
| NAME OF INSTRUCTOR | COURSE TITLE<br>Heating Systems Specialist |

BLOCK TITLE
Boiler Water Treatment and External Corrosion

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 6. OPSEC | .5/0 |

a. Given security pamphlet on operational activities related to AFSC 545X2, select the activities related to vulnerabilities for AFSC 545X2, ~~with 70% accuracy~~. . STS: 2 Meas: PC .
by correctly answering 5 out of 7 questions,

(1) OPSEC in squadron contingency operations

(2) AFSC 545X2 related OPSEC vulnerabilities

SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
SW J3ABR54532 001-VIII-6, OPSEC

Training Methods
Performance (.5 hr)

Instructional Guidance
Give students operations security handout and have them complete handout.

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# PLAN OF INSTRUCTION/LESSON PLAN PART I

| NAME OF INSTRUCTOR | COURSE TITLE |
|---|---|
| | Heating Systems Specialist |

BLOCK TITLE
Solar

| 1. COURSE CONTENT | 2. TIME |
|---|---|
| 1. Theory of Operation and Construction | 6/2 |

a. Given information, identify basic facts on theory of operation and construction features of solar heating, with 70% accuracy.
STS: 22a Meas: PC

(1) History
(2) Solar principles
(3) Heat flow
(4) Heat loss from buildings
(5) Insulation
(6) Collector types
(7) Collector hook-up
(8) Solar sitting
(9) Solar shading
(10) Types of racks
(11) Collector attachment
(12) Storage tanks
(13) Heat exchangers
(14) Transfer fluids
(15) Pressure hardware
(16) Solar controls
(17) Types of solar systems

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## SUPPORT MATERIAL AND GUIDANCE

Student Instructional Materials
WB J3ABR54532 001-IX-1, Theory and Construction Features
HUD Publication, Installation Guidelines for Solar DHW Systems

Audiovisual Aids
Transparencies, Solar Heating Systems Theory and Construction Features

Training Methods
Lecture/Discussion (5 hrs)
Demonstration (1 hr)

Instructional Guidance
Using transparencies, discuss the history of solar heating. Discuss solar principles, heat flow and heat loss from a building. Discuss insulation, collector types (including construction features). Discuss collector hook-up, solar sitting and shading. Discuss types of racks and collector attachment. Discuss types of storage tanks and heat exchangers. Discuss transfer fluids and their characteristics. Discuss pressure hardware. Discuss solar controls and the types of solar systems.

Instructor Reference Materials:
The Solar Homebook
Florida Solar Energy Center

| | |
|---|---|
| 8. Written Test and Test Critique | 1.5 hrs |
| (a) Written Test | (1.0 hr) |
| (b) Test Critique | (.5 hr) |
| 9. Course Critique and Graduation | 1.0 hrs |
| 10. MT: Predeparture Safety Briefing and End of Course Appointments | 4/0 hrs |

J3ABR54532 001-I-1, I-2, I-4, and I-5

Technical Training

# Heating Systems Specialist

# FUNDAMENTALS AND PIPE FITTING

June 1984

3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

DESIGNED FOR ATC COURSE USE
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ATC FORM 214 (JAN 76) OBSOLETES ATC FORMS 214, MAY 69, 522, NOV 63 AND 523, MAY 71. STANDARD COVERSHEET

This study guide was designed to guide you through your study assignments in the most logical sequence for easy understanding. The supplementary information section contains additional material required to keep you up-to-date in this subject. Answer the self-evaluation questions so you will better understand and retain the material you have studied.

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Supersedes SGs J3ABR54532 001-I-1, I-2 and I-4 thru I-5 June 1983. (Copies of superseded publication can be utilized until supply is exhausted.)

# EXPLANATION OF TERMS

ACETONE--A volatile fragrant flammable liquid used to absorb acetylene.

ACETYLENE--A gas used in welding and soldering.

ACQUIRE--To get something.

ANNEAL/ANNEALED/ANNEALING--A process used to soften metal.

APPRENTICE--A person learning a trade by helping a skilled worker.

ASSIGNMENT(S)--A given location.

AUTHORIZED--Officially allowed.

BACKFLOW--Term used to denote reverse flow.

BINDING--A valve stem stuck open or closed.

BLUEPRINT(S)--A copy of the plans for a building machine, piping system, etc.

BRAZIER--Pan used to hold hot coals.

BRAZING--To solder with a nonferrous alloy that melts at a lower temperature than that of the metal being joined.

CAPILLARY ATTRACTION--Heat which causes solder to flow into a joint.

CARBURIZING--A flame used in brazing which contains excess carbon.

CHAMFERING--The act of making a beveled edge.

CIVIL ENGINEER--CE commander.

CIVIL ENGINEERING--The squadron or section to which you will be assigned upon graduation.

CLASSIFICATION--Division of a class or group.

COMBUSTION--The burning process.

CONDENSATE--Steam turned back into water.

CONSERVATION--Saving of resources.

CONSTRUCTION--Made or made of, to build.

CONTROL(S)--Having power of or over.

COPPER--Reddish metallic element that is ductile and malleable and one of the best conductors of heat and electricity.

COPPER TUBING--Copper shaped to form a tube.

CROSS-CONNECTION--Term used to indicate connection between two piping systems.

DIAMETER--A straight line through the center of a circle.

DIRECTIVE(S)--A written order.

DRAWING(S)--A diagram.

DUPLEX--Having two parts that operate at the same time or in the same way.

ELECTRIC--Relating to or operated by electricity.

ELECTRICAL--Relating to or operated by electricity.

ENGINEERING SECTION--A part of civil engineering.

EQUIPMENT--Implements used in an operation or activity.

EXPERIENCE--Knowledge gained by performing.

EXTERIOR--Outside.

FACILITIES--Something built, installed or established to serve a purpose.

FIGURE(S)--Illustration.

FITTING(S)--Various controlling devices installed on a boiler.

FLARING--Opening or spreading outward.

FLEXIBLE/FLEXIBILITY--Bendable or pliable.

FULLY--All the way.

FUNCTIONS--Tasks or performances.

FUSION--The act of melting together.

GAUGES--Instruments with a graduated scale for indicating or measuring quantity.

HANDWHEEL(S)--A valve handle.

HEATING--The act of increasing the temperature.

HEATING SYSTEM(S)--A combination of equipment used to heat a specific area.

HEATING SYSTEMS SPECIALIST/TECHNICIAN--A fully qualified person working on heating equipment and/or supervising other personnel.

HEATING TOOL--A tool used to heat polyethylene pipe for fusion to take place.

HORIZONTAL--Parallel to the horizon.

INSIDE--On the inner side of.

INSPECTION--To check or look carefully.

INSTALLATION(S)--Air Force bases or properties.

INSTRUCTIONS--Procedures.

INSTRUMENT(S)--Referring to controls or special tools.

INTERIOR--Inside.

INTO--To indicate entry.

ISOMETRIC--A three-dimensional view of a print.

LEGEND--Used to explain symbols on a blueprint.

LIQUID--Neither solid or gaseous, having free movement of the constituent molecules among themselves without the tendency to separate.

LUBRICATION--To make slippery, usually with grease or oil.

MAINTAIN/MAINTAINING--To keep up.

MAINTENANCE--Keeping equipment in an existing state.

MAJOR COMMAND--Responsible to the assistant vice chief of staff.

MANAGEMENT--Judicious use of time, people, space and material to accomplish an end.

MANUAL--Worked by hand.

MANUFACTURER'S SPECIFICATIONS--Detailed, precise presentation written by a manufacturing company.

MATERIAL(S)--Things or tools needed to do a task.

MATTER--Anything that occupies space and has weight.

MAXIMUM--Most or highest limit.

MECHANIC(S)--A person who operates, maintains, services and overhauls heating equipment.

MECHANICAL/MECHANICALLY--Operated by a machine.

METAL--Any of various opaque, fusible, ductile and typically lustrous substances that is a chemical element.

METRIC--System of measurement.

MINIMUM--Least or lowest limit.

MISSION--Tasks or jobs to which an organization is devoted.

NEGATIVE PRESSURE--Same as vacuum.

NOMINAL--Minimum requirement.

OPEN(ED)--Not closed.

OPERATE/OPERATING/OPERATION(S)--A heating plant on the line.

OPERATOR--A person in charge of or running a central heating plant.

ORGANIZATION(S)--Structure of personnel and equipment functioning as a whole.

ORIENTATION--Act or process of being made aware of or about something new.

ORTHOGRAPHIC--Three separate views on a print.

OUTER--Referring to the outside.

OUTLET--Passage leading out of.

OXIDIZING--A flame used in brazing with excess oxygen.

OXYGEN--A gas that has no color, taste or odor, and is a chemical element; its symbol is $O_2$.

PACKING--Material used in a pump or valve to reduce friction and prevent leaks.

PAMPHLETS--Booklets or brochures usually containing information rather than directive material.

PERSONNEL--People of a unit or group.

PHOTOSTAT--To copy by a photo device.

PIPE FITTING(S)--Connecting pipe with the use of elbows, tees, unions, etc.

POLICIES--Rules which must be followed.

POLYETHYLENE PIPE--Pipe made out of non-metal material used for a variety of uses.

PRESSURE--Force exerted.

PRIMARY--Main.

PROPERTY/PROPERTIES--Land and buildings on an AF base.

REAMER--A tool used to remove burrs from inside pipe and tubing.

REGULATION(S)--Publications that announce policies, assign responsibilities and direct actions.

REGULATOR(S)--Device used to control flow.

REINFORCED--Material added to strengthen another material.

REQUIREMENTS--Needs or essentials.

RESIN PIPE--Pipe made out of non-metal material used in condensate return lines.

RESPONSIBILITIES--The quality or state or being answerable for.

ROTATING--To go around and around.

RUDIMENTARY--Of a primitive kind.

SAFETY--Condition of being safe from or causing hurt, injury, loss or damage.

SCALING--The process of measuring dimensions on a blueprint.

SIPHONAGE--Act of drawing something into.

SOLDER--Metallic alloy used when melted to joint metallic surfaces.

SOLDERING--The act of using solder.

SPECIALITY TRAINING STANDARD (STS)--A listing of related jobs or tasks.

SPECIALIZED PUBLICATIONS--Technical Orders (see Technical Orders).

SQUADRON(S)--Air Force unit or men higher and larger than a flight but lower and smaller than a group.

STANDARD PUBLICATIONS--Air Force regulations, manuals, pamphlets, etc.

STUFFING--Another word for packing (see packing).

SUBDIVISION(S)--A part of.

SUCTION--Act or process of exerting a force by reducing pressure.

SWAGING--A process of combining tubing.

SYMBOL--Sign or figure that represents or relates to a meaning or thought.

SYSTEM--A main part of.

TECHNICAL ORDERS--Specialized publications to furnish personnel with instructions for the operation, maintenance, inspection and overhaul of equipment.

TEMPERATURE--Degree of hotness or coldness measured on a definite scale.

TERMODYNAMICS--Physics that deals with mechanical action or relations of heat.

THERMOSETTING--Capable of becoming permanently rigid when heated or cured.

THREADED/THREADING--A job or task where you install NPT (National Pipe Threads) on the end of a piece of pipe.

TRAUMATIC SHOCK--Shock caused by injury.

TUBING--Material in the form of a tube.

USAF--United States Air Force.

UTILIZATION--The act of using or the state of being used.

VACUUM--A space completely empty or without matter.

VERTICAL--In an upright or up and down motion or position.

VIBRATION--Periodic motion in alternately opposite directions.

VOLUME--A space occupied as measured in cubic units.

WATER--Contains two parts hydrogen and one part oxygen, expressed as $H_2O$.

WATER COLUMN--Device that holds water vertically.

WELDING--Uniting metallic parts by heating and allowing the metals to flow together.

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

SG J3ABR54532 001-I-1

# ORIENTATION

## OBJECTIVE

The objective of this unit of instruction is to give you a brief but thorough orientation into the Heating Systems Specialist course.

## INTRODUCTION

No doubt you will have many questions concerning your future in the Air Force as a heating specialist. Let's point out first that your job must be pretty important when every building and person on the base is depending on you in one form or another. Just think, the hospital, dining halls, dormitories, and all other activities depend directly on the heating specialist for an adequate supply of steam, hot water and heat, in order to carry out their mission.

Looking at this brief introduction, you can see that the skills you acquire while attending this school will not only be valuable during your military career, they will be very useful to you when you return to civilian life. Well qualified heating specialists are much in demand and in most areas they earn top salaries.

Most people think of a heating specialist as one who shovels coal or stokes a fire all day; however, this is not true at all. As the standards of living rose, so did the complexity of heating systems. Today's modern heating plants and systems make use of various types of complex equipment and almost totally automatic operation. This requires a great deal of skill and flexibility on the part of the heating specialist.

So this is your chance to begin qualifying yourself for an outstanding military career and a highly respected and well paid job upon returning to civilian life. Make the most of it. Take advantage of all the opportunities that come your way. In doing so, you will be serving the Air Force well and at the same time doing yourself a great favor. Remember that the experience gained while in the Air Force will count as previous experience when applying for a civilian job.

## INFORMATION

### Orientation

#### Welcome

We in the Heating Systems Specialist course would like to welcome you not only to our course, but also to Sheppard AFB, Texas. We feel the heating career field is one of the most important in civil engineering. We'll try and convey this to you on a continuing basis, so that you'll understand the importance of your part in the US Air Force.

SAFETY GLASSES. In some blocks of this course, you will be required, if you need glasses, to have and wear electrical safety glasses. For the pipeline students, these glasses should have been issued during basic training at Lackland AFB. For all other students, you should already have the glasses from your home or previous base. If you do not have these glasses, you'll have to make an appointment at the base hospital to receive them. Failure to have the safety glasses by the required time will result in your training being stopped at that point.

LENGTH OF TRAINING DAY. Your training day consists of six hours classroom time. You will be required to complete two hours of directed study assignments for four days per week. Classroom training has precedence over all other duties except emergency sick call, emergency leave, or any absence authorized by the 3770th Technical Training Group Commander.

ASSIGNMENTS. You may receive your assignments at any time, usually during Block II or later. All assignments are handled by CBPO and your squadron, not the instructors in the heating course. All questions pertaining to assignments should be directed to the Assignments Section of CBPO.

Overview of Course Content, Its Goals and Administration

OVERVIEW OF COURSE. The Heating Systems Specialist course is 45 training days in duration. The following is the block number and title:

- - -Block I -- Fundamentals and Pipe Fitting

- - -Block II -- Basic Electricity

- - -Block III -- Controls, Troubleshooting and Oil Burners

- - -Block IV -- Solid, Gas Fuel Burners and Warm Air Distribution Systems

- - -Block V -- Hot Water Heating Systems

- - -Block VI -- Central Plant and High Temperature Water Heating Systems

- - -Block VII -- Boiler Maintenance and Steam Distribution Systems

- - -Block VIII -- Boiler Water Treatment and External Corrosion

- - -Block IX -- Solar

COURSE ORGANIZATION. In the Air Force you'll find that everyone has a boss. This is needed to maintain discipline and high efficiency. In this course, as in all courses, the chain of command starts with the class leader who is directly responsible to the class instructor. The chain follows upward in this case to the Commander of the 3770th Technical Training Group. Your instructor will give you the names of the personnel who come in this chain of command as illustrated in Figure 1.

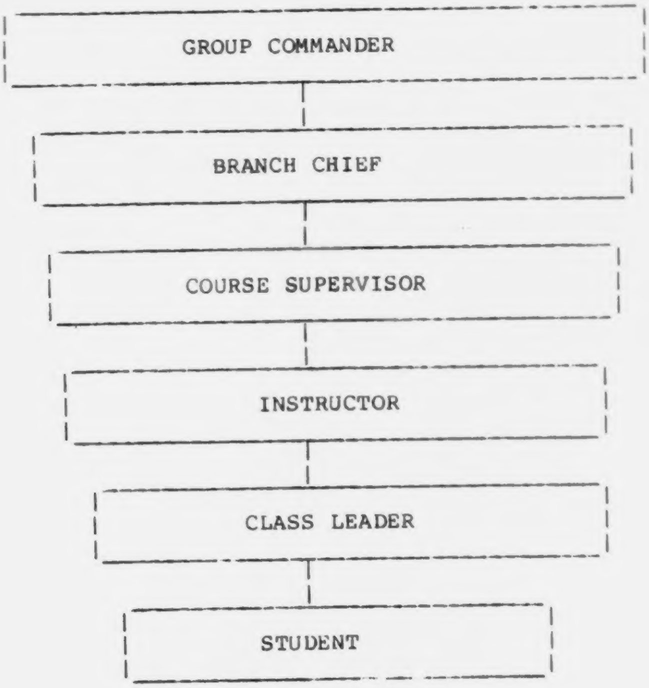


Figure 1. Chain of Command

COURSE OBJECTIVES AND GOALS. The objectives and goals of this course is to give you a general knowledge of AFSC 54532, Apprentice Heating Systems Specialist. You will also perform certain apprentice duties as outlined in the current Specialty Training Standard. We will also give you information that will give you an insight as to what to expect when you graduate from this course and go to your next duty station. Remember, we do not expect you to know everything about the heating field; rather, just have a general knowledge of the duties and responsibilities of AFSC 54532 and be able to perform required tasks with help on the hardest parts (partially proficient).

SCHOOL POLICIES. The following is a list of school policies that we expect to be followed:

___ Shift and Class Hours. At present, the Heating Systems Specialist course is operating on S-shift. Class hours start at 0610 hours each school day and terminate at 1200 hours. Your instructor will have the classroom open at 0600 hours for his classroom preparation time.

___ Class Attendance. Class attendance is mandatory unless you go on emergency sick call, emergency leave, or you are excused from class by the 3770th Technical Training Group Commander. You will be considered late to class after 0610 hours. If you are late, an ATC Form 62 will be filled out by your instructor and forwarded to your squadron for action.

___ Emergency Leave and Sick Call. Emergency leave must be verified by the Red Cross through your school squadron. School squadron personnel will handle all paperwork. You may go on emergency sick call at any time. Normal sick call appointments will be made by school squadron personnel. It would be best for normal sick call appointments to be made for the afternoons, so as not to miss any school.

___ Student Dress and Personal Hygiene. Uniforms, shoes, haircuts and personal hygiene will conform to AFR 35-10 and supplements thereto. (TO THE LETTER) Violators will be warned once; if this fails, you will be counseled by the course supervisor; and if this fails, you will be sent back to your school squadron for disciplinary action. Uniform wear for the heating course will be fatigues except on graduation day. On graduation day you may wear combinations 1, 2, 2a, 4, or 4a.

___ BREAK SCHEDULE. The break schedule for the heating course is on each classroom bulletin board. Break times will be followed to the letter and monitored closely by the course supervisor.

___ SMOKING REGULATIONS. For students, there will be NO SMOKING in Building 1927. The smoking area for students is outside in the designated area. All cigarette butts will be placed in the proper receptacle. All break and smoking areas will be monitored by supervisory personnel and names taken of personnel breaking the rules.

___ CLEAN-UP SCHEDULE. Clean-up schedules will be posted on each classroom bulletin board. All clean-up will be accomplished starting at 1150 hours unless a hazardous condition exists.

## Responsibilities of Student

You have responsibilities both here in school and to your squadron. You must abide by the rules set by the USAF and/or its designated representatives.

## Importance of Graduate's Performance to AF Mission

The importance of your performance here cannot be over emphasized. The better you understand and perform here, the better you'll be able to function and perform at your next duty station. This will also make your adjustment to the Air Force life much easier. Lastly, and maybe most importantly, you will have the self-satisfaction of doing your best at whatever job you are called upon to do.

## Benefits of CCAF and Its Assignment of Credit at Regionally Accredited Institutions

What is CCAF? The Community College of the Air Force is one of the best educational opportunities in the Air Force. The people to gain the most from this program are the basic airmen with previous college credit on their records. In the Air Force you get college hours for basic training and hours for each formal technical training school thereafter. The basic heating course is worth semester college hours toward your CCAF certificate. To find out more about CCAF, visit your local Base Education Office, either here at Sheppard AFB or your next duty station.

## Student Progress Policies

PROGRESS CHECKS. In the heating course we sign-off criterion checklists after you complete a project or projects. Failure to complete a project will result in an unsatisfactory mark on your criterion checklist. This will have to be corrected before you can take the block test. Your instructor further evaluates you each and every day to insure that you are progressing satisfactorily.

WRITTEN TESTS. At the end of each block, you will be given a 25 or 50 question multiple-choice block test.

PROFICIENCY ADVANCEMENT. Some of you may have experience in your chosen career field or college training which would permit you to be advanced to classes ahead of you. If you feel that you could pass the tests for a block, you should ask your instructor for an interview with him and his supervisor. They will determine whether to give you the test. Should you be given the test and make a passing grade, you could be advanced a class if one was available.

SCHOOL GRADING. You must attain a minimum passing score of 60 percent in each block.

## Honor Graduate Program and Student Recognition

This is a special program for those students who maintain a high overall block test average grade. The grade cut-off is determined by the percent of honor graduates up to that particular time. In addition to your regular diploma, you will receive a special honor graduate certificate and a special letter will be sent to your parents. Even if you maintain a high enough grade average, you will not be eligible for the honor graduate program if you have an UIF file in the squadron.

## Effective Study Techniques

ATC Programmed Text 52-11, Study Skills, will give you an insight into proper and effective study procedures. This handout will be given as an extra homework assignment. One thing to remember, we are all different, both physically and mentally; thus our capabilities are different and our study procedures will also be different.

## Ground Safety

SEAT BELTS. AFR 127-5 states that all military personnel, both in military and civilian vehicles, must wear seat belts. On Sheppard AFB, the Security Police make random seat belt checks with non-conformist issued citations. Remember, buckle up for safety!

## Procedures for Shelter Exercises and Fire Drills

FIRE DRILL. In the event of a fire drill or alert, all personnel will file outside through the nearest exit or door. Move away from the building and watch out for fire-fighting equipment. Stay out of the building until an "all clear" is given.

TORNADO ALERT. In the event of a tornado alert, all personnel in building 1927 will file to the center of the building. Stay calm and do what your instructors tell you. Stay in your designated shelter area until the "all clear" is given.

NUCLEAR ATTACK. In the event of a nuclear alert, we will have plenty of advance notice. All students will be marched back to their respective squadrons and housed in their own shelter. Instructors will go immediately to their designated shelter.

Objective

Pre-narrated slide: ATS 75-32, Student Critique Program, will fully explain the critique program. Remember, you can fill out a critique form at any time. Turn the completed form over to your instructor or the course supervisor. BE SPECIFIC ABOUT ALL COMPLAINTS OR APPRAISALS!

Conservation of Training Materials, Resources and Energy

Energy conservation cannot be over-emphasized. The availability and cost of energy are getting more critical every day. Everyone is expected to conserve in every phase of energy consumption area; specifically, electricity, fuel, and water resource areas.

Disposition of Eliminees

First, there are two ways which you may be eliminated from the heating course. One way is for disciplinary reasons and the other is for academic reasons. When it's decided that you are to be eliminated, all the paperwork is forwarded to the Elimination Faculty Board. The Faculty Board makes the final decisions. Once eliminated, you are sent back to your squadron to await further classification and reassignment by CBPO.

Types, Use and Care of Instructional Materials

Study guides, workbooks and programmed texts are the types of instructional materials used in this course. They are used to help clarify the instructor's lectures and presentation during the day. It is up to you, the student, to maintain this material. In fact, the study guide will have to be maintained to a condition that they can be returned to the instructor at the end of each block. The workbooks and programmed texts are yours to keep.

Necessity of TDY Personnel Clearing Through In-Processing at Base Personnel

All TDY personnel must clear through in-processing at CBPO. This will insure that you are enrolled in the proper course and assigned to the proper squadron.

Instructions for Completion of STTC Form 120, Processing Checklist - TDY Personnel

STTC Form 120, In-Processing Section, must be completed prior to class start date. The form will be kept in the supervisor's office and returned one day prior to graduation. Diplomas will not be issued to any student until all out-processing has been completed and the checklist again returned to the instructor.

# CIVIL ENGINEER ORGANIZATION, SAFETY, AND PUBLICATIONS

## OBJECTIVE

The objective of this unit is to explain the civil engineering organization, related career ladders in the 54 (mechanical/electrical) career field, and duties, responsibilities, progression of the 545X2 career field, and publications.

## INTRODUCTION

You have learned many new things since becoming a member of the United States Air Force. Basic military training taught you the fundamentals of military life, now it's time to supplement this training with information about your newly chosen career field. First, you must gain knowledge about this organization to which you are assigned - Civil Engineering (CE), its different branches, sections, offices, etc. Next, is the branch of CE your Air Force Specialty (AFS) is assigned -- the mechanical/electrical branch. Your particular career field is next -- heating systems.

Air Force publications are a means of communication. They announce policies, prescribe procedures, and furnish instruction and information necessary to accomplish the mission of various activities.

## INFORMATION

### Mission and Organization of Civil Engineering Units

An important part of being a member of the Air Force is striving to accomplish a mission. This is done by progressing in your field. Hopefully, you have enthusiasm, initiative and the desire to progress. The experience you gain will not only benefit you as an individual, but will provide the Air Force with the type of personnel that will keep it a highly technically skilled organization.

UNIT. A part of a military establishment that is part of a prescribed organization, (Squadrons), made up of a Non-Commissioned Officer in Charge (NCOIC), and a prescribed number of both military and civilian personnel depending on the mission of the Squadron.

SQUADRONS. A part of a military establishment that is part of a prescribed organization, (GROUP), made up of all units assigned to the prescribed organization and headed by a commissioned officer.

GROUP. A part of a military establishment that is part of a prescribed organization, (WING), made up of all squadrons assigned to the prescribed organization and usually headed by a field grade officer.

The prime mission of the civil engineering unit is to acquire, construct, operate and maintain real property facilities. Included as part of the primary mission are the management, engineering and other support work and services that relate to real property. Such areas as fire protection, traffic engineering, utilities, landscaping and grounds maintenance, sanitation, airfield pavements, and base recovery from natural and man-made disasters are all part of the responsibility of base civil engineering.

Base civil engineer responsibilities and functions are specifically spelled out by Air Force regulations. Think for a moment of all the real property facilities on your base. The enormous responsibility becomes evident when you consider the number and the cost of the properties and facilities with which base civil engineering is concerned. How are these responsibilities met? Primarily, through a well-organized unit with each subdivision of that unit responsible for certain functions. Civil engineering units are generally standardized as outlined in instructions issued by Headquarters USAF. Major commands, however, are authorized to make minor changes in the organizational structure to fit the needs of a particular base.

Base civil engineering organizations are divided into certain components or subdivisions. Figure 2 illustrates the organizational structure of a base civil engineering unit. By studying the figure you can easily see each level of command, from the base civil engineer down to the individual shops. Normally, the civil engineering unit on a base is designated as a civil engineering squadron. On some bases, however, the civil engineering unit has a group designation. This, of course, depends on the size of the base and the amount of real property facilities. A large base may have a civil engineering group, whereas a small base would have a squadron. In either case, the civil engineering unit is organized basically as shown in the figure.

To carry out its support functions, a civil engineering unit must operate in conjunction with other units on the base. The transportation squadron, for example, provides vehicles for the civil engineering operation; the communications squadron provides telephone and other communications equipment; and other units provide such services as supply, food and security police protection. In turn, base civil engineering provides these base units not only with buildings and facilities necessary for their operations but also with the maintenance of the facilities. Base civil engineering is responsible for all the real property facilities that are required by the base.

AFR 85-1, Resources and Work Force Management gives procedures to Base Civil Engineering (BCE) for managing work done in service through civil engineering squadron or self-help.

Work Identification

There are a number of ways that people may make their desires for work or services known to Civil Engineering. One of these ways is to use AF Form 332, BCE Work Request.

This work request form serves dual purposes. It is both a work request and a work approval or disapproval document.

Since you may desire to submit one of these forms yourself, it may be worthwhile to look at the criteria for submitting one. At this point you may be scratching your head wondering why you might have to submit a work request! Let's first look at the criteria, then we will explain why or when you may be required to prepare one.

For organizations other than Civil Engineering, the AF Form 332 is used to request:

___ New Work. This is all construction requirements including the permanent removal or initial installations of RPIE; new work on leased facilities; all reimbursable work and services; and all non-reimbursable work and services except when such work and services are specific civil engineering responsibilities.

___ The repair of damages to real property caused through neglect or abuse.

___ All self-help work, except that work defined as homeowner's responsibilities in AFR 91-1 and/or Base Family Housing Brochure.

The AF Form 332 also serves as a work approval document for work that is within the Base Commander's approval authority. It is used to approve or disapprove the work stated in the above-listed items, and to approve work for:

___ In-service minor construction requirements initiated by base civil engineering and costing over $100 for Military Family Housing, and $500 for base work.

___ Projects that are to be accomplished by contract, regardless of the work classification.

Perhaps you have already caught the item that might explain your need to prepare and submit a 332. It is the first item in the paragraph directly above. If you are living in the barracks and you would like to have a partition put up, or a cabinet installed, or any other item you think might be approved, then you will have to prepare and submit a work request.

Work Authorization

As we mentioned before, all the work you do must be authorized by one of the civil engineering authorization documents. You may be required to use one of these forms in performing your job.

BASE CIVIL ENGINEER ORGANIZATION CHART

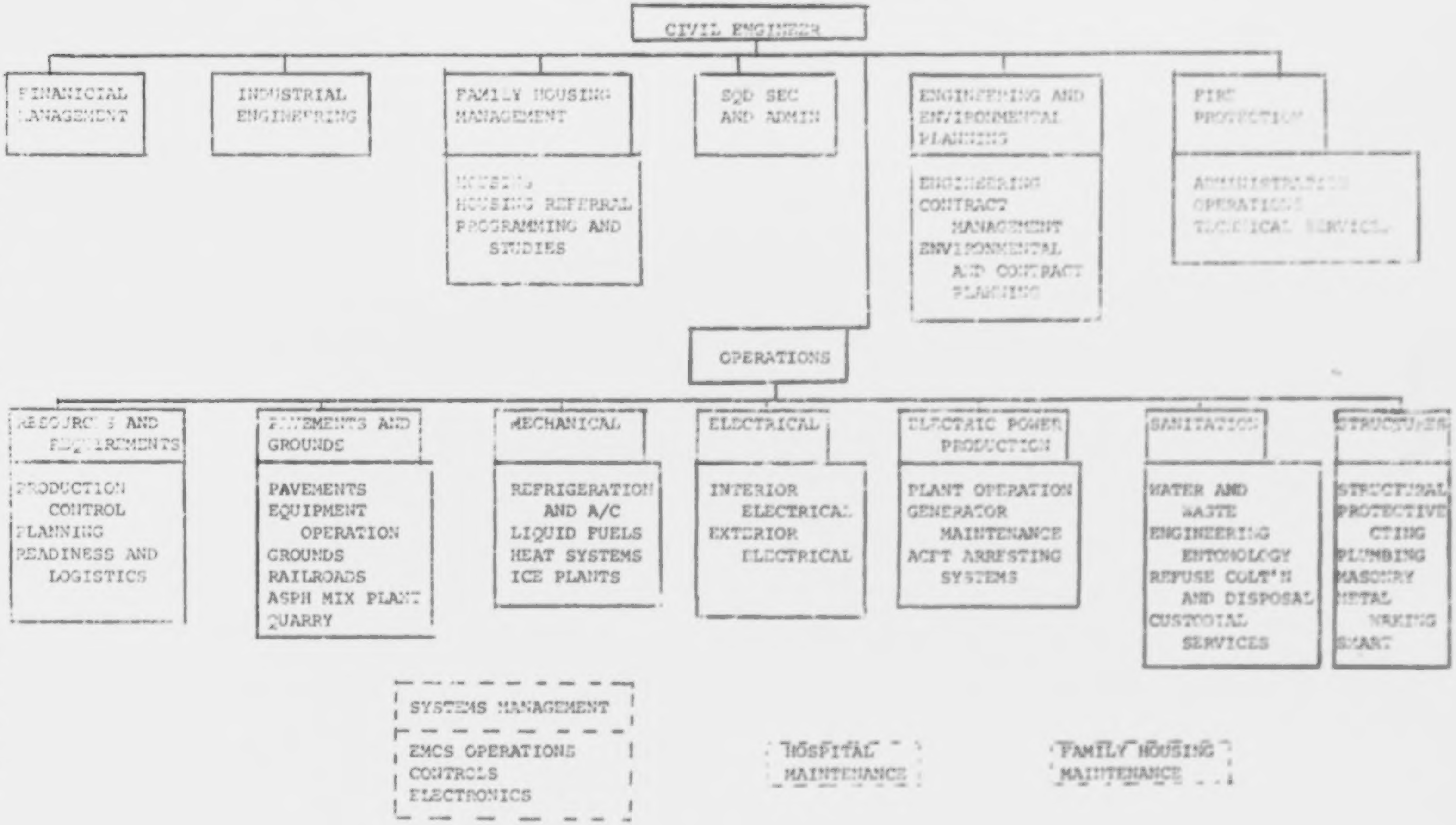

CIVIL ENGINEER
FINANCIAL MANAGEMENT
INDUSTRIAL ENGINEERING
FAMILY HOUSING MANAGEMENT
HOUSING
HOUSING REFERRAL
PROGRAMMING AND STUDIES
SQD SEC AND ADMIN
ENGINEERING AND ENVIRONMENTAL PLANNING
ENGINEERING
CONTRACT MANAGEMENT
ENVIRONMENTAL AND CONTRACT PLANNING
FIRE PROTECTION
ADMINISTRATION
OPERATIONS
TECHNICAL SERVICES
OPERATIONS
RESOURCES AND REQUIREMENTS
PRODUCTION CONTROL
PLANNING
READINESS AND LOGISTICS
PAVEMENTS AND GROUNDS
PAVEMENTS
EQUIPMENT OPERATION
GROUNDS
RAILROADS
ASPH MIX PLANT
QUARRY
MECHANICAL
REFRIGERATION AND A/C
LIQUID FUELS
HEAT SYSTEMS
ICE PLANTS
ELECTRICAL
INTERIOR ELECTRICAL
EXTERIOR ELECTRICAL
ELECTRIC POWER PRODUCTION
PLANT OPERATION
GENERATOR MAINTENANCE
ACFT ARRESTING SYSTEMS
SANITATION
WATER AND WASTE
ENGINEERING ENTOMOLOGY
REFUSE COLL'N AND DISPOSAL
CUSTODIAL SERVICES
STRUCTURES
STRUCTURAL
PROTECTIVE CTING
PLUMBING
MASONRY
METAL MAKING
SMART
SYSTEMS MANAGEMENT
EMCS OPERATIONS
CONTROLS
ELECTRONICS
HOSPITAL MAINTENANCE
FAMILY HOUSING MAINTENANCE

Figure 2. Base Civil Engineering Organization Chart

### Service Call Unit

Service Call Unit receives verbal request for work and controls rapid response service, (Do-It-Now (DIN) Vehicle).

### AF Form 1879, Service Call/Job Order Record

AF Form 1879, BCE Job Order Record, is a document used to authorize work of a minor nature with a minimum of administrative costs.

The form is unique in that five different types of work can be authorized. It can be used to authorize:

___ Service Call Work: Emergency and Urgent Job Orders

___ Routine Job Orders: Job orders accumulated in a hopper by geographical area and scheduled as work packages. Most bases are divided into 18 different zones. Once a week these job orders are screened and packaged for scheduling to the shops.

___ In-Service Work Plan Job Orders (IWP): A plan used to time phase work to be done by the shops.

___ Self-Help Work: Requests to do self-help work must be closely reviewed to determine the requester's ability to complete the work.

___ Smart Team Work: Structural Maintenance and Repair Team, (SMART), is used to do work in high use facilities. It is made up of a team of workers with various skills and work out of a trailer.

### AF Form 327, Base Civil Engineer Work Order

The BCE work order is designed to provide the detailed planning and control necessary to efficiently accomplish large or complex jobs. You will notice from the last sentence the words detailed planning and control. Normally, job order work does not require this detailed planning. The level of control considered necessary to effectively and economically accomplish a job is a basic determining factor for deciding on the use of an individual work order or a job order for authorizing the work.

### Management and Utilization of Material Resources

All jobs and tasks assigned to you should be completed in a minimum amount of time using only the necessary materials and equipment. Cost is already figured into your work. Fraud, waste and abuse cost us both money as taxpayers and as cost overruns on fiscal budget.

### Duties and Responsibilities of AFSC 545X2

A good worker must know what he is expected to do. Ability is important but, without a complete knowledge of the duties and responsibilities of a job, ability may be ineffective. As an apprentice heating systems specialist, your duties are almost the same as the heating systems specialist (5-skill level). However, the responsibilities attached to your duties are not as great.

How can you tell just what your duties and responsibilities are? They are spelled out in an Air Force Regulation, AFR 39-1, Airman Classification. Air Force specialties are written for each level within each career field ladder. The specialty description consists of four sections: (1) specialty summary, (2) duties and responsibilities, (3) specialty qualifications, and (4) specialty data.

Your specialty description AFSC 54532 has been reproduced for your convenience and study.

# AIRMAN AIR FORCE SPECIALTY

## HEATING SYSEMS SPECIALIST

### 1. SPECIALTY SUMMARY

Installs, maintains, repairs, and operates heating plants, systems, and equipment. Related DOD Occupatioal Subgroup: 720.

### 2. DUTIES AND RESPONSIBILITIES

a. Installs and maintains heating systems components and equipment. Interprets detailed blueprints, drawings, and specifications for heating plants, systems, and components. Installs air, steam, water, and solar heating and distribution systems components and equipment such as furnaces, boilers, stoves, heat exchangers and pumps, burners, blowers, fans, strainers, solar collection and storage tanks and radiant heating fixtures; oil, gas, or coal fuel handling distribution and storage facilities and equipment; demineralizers, deaerators, and proportioning feed pumps air distribution ducts; water and steam distribution and pneumatic control pipes, tubes, and valves; pressure and temperature gages and recording devices. Shapes, sizes, and corrects high and low pressure piping and tubing. Observes piping distribution system for evidence of corrosion. Welds heating systems components and supporting devices using oxyacetylene equipment. Uses special tools, materials, and procedures for coupling and insulating high pressure and high temperature piping and components. Mounts, connects, and adjusts electrical components such as transformers, motors, electrodes, relays, solenoids, switches, and thermostats. Conducts tests of installed equipment for proper assembly of components and compliance with technical orders, manufacturer's handbooks, and local procedures.

b. Operates and maintains central heating plants. Operates and maintains plant components and equipment such as boilers, burners, pumps, blowers, fans, steam turbines, and stokers; oil, gas, or coal fuel handling equipment, storage facilities, and fly ash collectors; demineralizers and water treatment equipment. Operates oil, Refuse Derived Fuels (RDF), gas biomass, or coal-fired boilers. Determines fuel requirements. Inspects shipments of coal, wood, and other fuels to verify conformance to specifications. Collects and prepares coal samples according to Bureau of Mines recommended procedures. Fires, blows off, and cleans boilers. Operates manual controls or sets automatic controls to supply oil or gas to burners or to operate stokers and chain grates for coal-fired, biomass or RDF boilers. Hand fires coal-burning boilers to maintain efficient operation. Adjusts draft and fuels to load for efficient operation. Operates boilers for efficient combustion by visual analysis and by use of flue gas analyzing equipment, draft gauges, and stack thermometers. Checks and adjusts safety valves. Observes water and steam gauges and adjusts controls to maintain appropriate pressures and levels. Synchronizes recording devices with operation of electric, pneumatic, and mechanical sensing and control devices. Operates water feed systems. Performs chemical analysis of boiler water and calculates chemical feed rates. Operates and regulates demineralizers, water treatment equipment, deaerators, and proportioning feed pumps in conjunction with water feed systems to prevent scale and corrosion damage and maintain safe operation of boilers. Posts entries in operation, inspection, and maintenance records. Records meter readings, fuel consumption, and other pertinent data in equipment performance logs.

c. Maintains and repairs building heating systems. Maintains and repairs warm air, hot water, and low or medium pressure steam heating systems. Maintains heating systems components such as furnaces, water and steam boilers, stoves, and radiant heating fixture; steam, hot water, solar and warm air distribution systems, pipes, and ducts; and heat exchangers and pumps. Performs oil-burning unit maintenance functions such as testing and adjusting, starting, timing, recycling, and safety switches; and cleaning, adjusting, or replacing nozzles, atomizing cup, needle valve, motor, blower, transfer, and protectorelay. Performs gas burning unit maintenance functions such as cleaning, adjusting, or replacing pressure regulators, solenoid and diaphragm valves, and pilostats; electronic ignition and flue damper systesm, and detection, repair, or replacement of leaking distribution lines. Performs solid fuel burning unit maintenance functions such as cleaning, repairing, or replacing of doors, baffles, plates, stovepipes, firebrick, and stoker mechanisms; and lubrication of motors and fans, recording devices; and fuel, air, water, and steam flow control servo-mechanisms.

Uses and interprets instruments and equipment such as pyrometers, voltmeters, velometers, ammeters, flue-gas analyzers, hydrometers, pressure gauges, and recording thermometers to detect heating systems and related control malfunctions and adjust system components for efficient and safe operation.

d. Maintains tools and equipment. Removes dirt and grease from tools and equipment and makes minor repairs. Lubricates metal parts to prevent rusting and corrosion. Sharpens edges of cutting tools.

e. Supervises heating systems personel. Conducts on-the-job training in functions such as installation, operation, maintenance, and repair of heating systems, plants, and equipment. Assigns work and examines completed repairs for compliance with local procedures and applicable technical orders.

## 3. SPECIALTY QUALIFICATIONS

a. Knowledge. Knowledge of principles and theory of pressure, vacuum, vaporization, condensation, heat conduction, radiation, and convection as applied to air, steam and water, nomenclature, types, sizes, and purposes of furnaces, boilers, heat exchangers and pumps, and heating systems components; standard types and specification of fuel such as coal, biomass, RDF, oil, and gas; techniques for installing, operating, and repairing heating equipment, systems, and fixtures; blueprint reading; and safety codes and practices is mandatory. Possession of mandatory knowledge will be determined according to AFR 35-1.

b. Education. Completion of high school with courses in shop and mathematics is desirable.

c. Experience. Experience in functions such as operation of high-pressure boilers or installation, repair, and maintenance of heating systems, equipment, and fixtures is mandatory.

d. Training. Completion of a basic heating systems course is desirable.

e. Other. Physical qualification for military drivers according to AFR 160-43 is mandatory for entry into this AFSC.

## AIR FORCE OCCUPATIONAL SAFETY AND HEALTH STANDARDS (AFOSH STANDARDS)

These standards are used in the heating specialty and you should be familiar with the ones pertaining to the subjects taught in this school and the ones pertaining to your job. AFR 0-17 covers Air Force Occupational Safety and Health Standards (AFOSH).

AFOSH STDs 127-1, Walking Surfaces
127-4, Portable Ladders
127-5, Welding, Cutting and Brazing
127-6, Fixed Ladders
127-7, Scaffolding
127-11, Electrical Installation and Equipment
127-12, Machinery
127-31, Personal Portective Clothing and Equipment
127-38, Hydrocarbon Fuels, General
127-40, Fuel Storage Systems
127-43, Flammable and Combustible Liquids
161-1, Respiratory Protection
161-2, Industrial Ventilation
161-4, Exposure to Asbestos
161-8, Permissible Exposure Limits for Chemical Substances

## HAZARDS OF THE 545X2 SPECIALTY

As your knowledge of your specialty increases, you will become more aware of the hazards that we as heating system specialists deal with on a daily basis. Listed below are the four main hazards in our specialty. By the end of the course you should be able to name at least two more hazards that you will be exposed to.

- Electrical
- Flammable
- Chemical
- Steam/Hot Water

## Types of Publications

### Specialized

The most important of the specialized publications are technical orders. They provide specific technical information, instructions and safety procedures pertaining to the installation, operation, maintenance and modification of Air Force equipment and materials. The technical order system does not apply to experimental equipment, or to the operation and maintenance of real property equipment. Because of the variety and complexity of heating equipment, it would be impossible to maintain technical orders covering all of the different manufacturers' equipment.

Technical Order 00-5-1, AF Technical Order System, explains the TO system in detail.

Technical Order 0-1-01, Numerical Index and Requirements Tables, gives the indexes for the different categories of technical orders.

### Standard Publications

There are eight different types of standard publications; the three types that we will be covering are: regulations, manuals and pamphlets.

AFR 0-2 is the Numerical Index of Standard and Recurring Air Force Publications.

AIR FORCE REGULATIONS (AFRs). AFRs contain directives and policy instructions and assign responsibility for carrying out the instructions. They not only tell "what to do", but they also frequently prescribe, in general terms, the procedures for accomplishing the action. More specific details on how to accomplish the specific actions are usually provided in Air Force manuals.

AIR FORCE MANUALS (AFMs). Manuals may be considered as "working handbooks". They contain permanent and detailed instructions, procedures and techniques that operating personnel are to use in performing their duties. Manuals may be compared to the "How To Do It" articles you find in popular science magazines or books on how to repair your automobile.

AIR FORCE PAMPHLETS (AFPs). Pamphlets are booklets or brochures similar to manuals, but not so thorough in their coverage. They are usually merely information, not directive; that, they provide information but do not direct or "order" you to do anything. However, some pamphlets are directive in nature. One such directive pamphlet with which you should become thoroughly familiar is AFP 85-1, Electrical Facilities Safe Practices Handbook. Pamphlets cover a wide range of rather specific subjects such as personal affairs, voting, safety, first aid, and military and dependents' information on overseas areas.

The regulation that covers heating is AFR 91-7, Heating, and the manuals that cover heating are AFM 85-12, Volume I, Operation and Maintenance of Central Heating Plants and Distribution Systems; and AFM 85-12, Volume II, Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization.

### SUMMARY

Today, you have had a brief but complete orientation into the Heating Systems Specialist course including all school policies and regulations. These policies and regulations will be followed to the letter and if not, disciplinary action will be taken.

Civil engineering organization was also covered including: groups, squadrons, work identification, work authorization, and management and utilization of material resources.

Related career ladders in the 54 (mechanical/electrical) career field were discussed and the duties, responsibilities and progression of AFSC 545X2.

The principles and objectives of ground safety were discussed. Also discussed were Air Force safety directives, use of proper personnel protective equipment, and first aid procedures.

Technical Orders are published by the Air Force to furnish personnel with instructions for the operation, maintenance, inspection and overhaul of equipment.

QUESTIONS

1. What is the main objective of the J3ABR54532 001 course?

2. What organization will you most likely be assigned to after graduation from this course?

3. How many Air Force specialties are in the (54) mechanical/electrical career field?

4. What is the number and title of the Air Force publication that has your Air Force specialty description?

5. Name four types of personnel protective equipment used in the heating field.

6. Which TO will explain the TO system?

7. What type information is found in AFRs?

8. What type information is contained in AFMs?

REFERENCES

1. AFR 39-1, Airman Classification Regulation
2. AFR 85-1, Resources and Work Force Management
3. TO 005-1, Air Force Technical Order System
4. AFR 0-2, Numerical Index of Standard and Recurring Air Force Publications
5. TO 0-1-01, Numerical Index and Requirement Tables

# PIPE FITTING

## OBJECTIVE

The objective of this unit of instruction is to aid you in constructing a piping system.

## INTRODUCTION

Different types of pipes and fittings are used in the installation of a heating system. Each type of pipe or fitting is made for a specific use, depending on the installation and its requirements. Some pipes and fittings are made in different weights and strengths for use in gravity or pressure systems. In either case they are made so that they can be installed to provide watertight, gastight or airtight joints. Many materials are available for use in installing permanent heating systems. Among those commonly used are iron, steel and copper. Plumbing and heating practices and the physical characteristics of these materials are the basis for establishing specific uses for each type of pipe or fitting.

It is important for the heating mechanic to have a good knowledge of fitting iron, copper and steel pipe. First, he must study his blueprints and plan his job so that the proper materials and equipment for the job will be procured. The loss of time and materials can be prevented if the correct fittings are procured first. A good mechanic will always prepare a checklist to insure that the proper tools and equipment are on hand, and also that the job is properly planned before it is started.

## INFORMATION

### Pipe

#### Purpose of Pipe

A pipe for plumbing purposes is a hollow cylinder used for conveyance of liquids or gases and is usually threaded at the ends for coupling. Pipe that is used by the heating specialist is measured by the inside diameter.

#### Types of Pipe

BLACK IRON (UNCOATED). Black iron is composed of mild steel mixed with cast or pig iron. This type of pipe is most commonly used by the heating field. It is used for compressed gases (air, gaseous fuels), steam and condensate returns, and oil. However, it is not recommended for sewer lines due to rust and stoppage.

STEEL. Steel pipe is a composition of scrap iron.

GALVANIZED (COATED). Coated pipe is either black iron or steel pipe that has been dipped in a zinc bath solution. It is used for hot and cold water distribution, drain lines. It is not normally used for natural gas lines due to flaking action of the zinc coating.

#### Sizes of Pipe

Sizes of pipe that you may work with are: 1/8", 1/4", 3/8", 1/2", and 3/4", 1", 1-1/4", 1-1/2", 2", 2-1/2", 3", 3-1/2", 4", 5", 6", 8", 10" and 12".

However, the most common sizes are: 3/8", 1/2", 3/4", 1", 1-1-4", 1-1/2" and 2". The average length of each piece of pipe furnished the Air Force is 21 feet.

#### Classes of Pipe

There are three classes of pipe used for heating systems:

________ Standard Weight (125 psi).

______ Extra Strength (250 psi).

______ Double Extra Strength (600 psi).

## Pipe Fittings and Their Use

Pipe fittings are measured by inside diameter and the size is proportionate to the outside diameter of the pipe. Example: a 1/2" fitting will accommodate a 1/2" pipe although the inside diameter of the fitting may be 3/4". Pipe fittings are fabricated in malleable iron for use with steel pipe and in black iron or galvanized. Fittings for brass pipe are plain or chrome.

### Types of Fittings

Following are types of pipe fittings that you as a heating specialist may be using at some time. See Figure 3.

ELBOWS

____ Female threads (inside)

____ 90 degree (makes a 90-degree change in direction)

____ 45 degree (makes a 45-degree change in direciton)

____ 90 and 45 degree street elbows

  ____ One female and one male thread

  ____ Allows for close installation of fittings

  ____ Eliminates a pipe nipple

____ Reduce elbow

  ____ 90 and 45 degrees

  ____ Two female threads

  ____ Used to reduce from one size to another

TEES

____ Three female threads

____ Used to pick up a branch run at a 90-degree angle

____ Reducing tees

  ____ Used to couple three lines of different sizes

____ Service tee

  ____ Two female and one male thread

  ____ For close installation

  ____ Eliminates use of a nipple

CROSS

____ Four female threads

____ Four outlets 90 degrees apart

____ Used on most steam boilers below and above water column

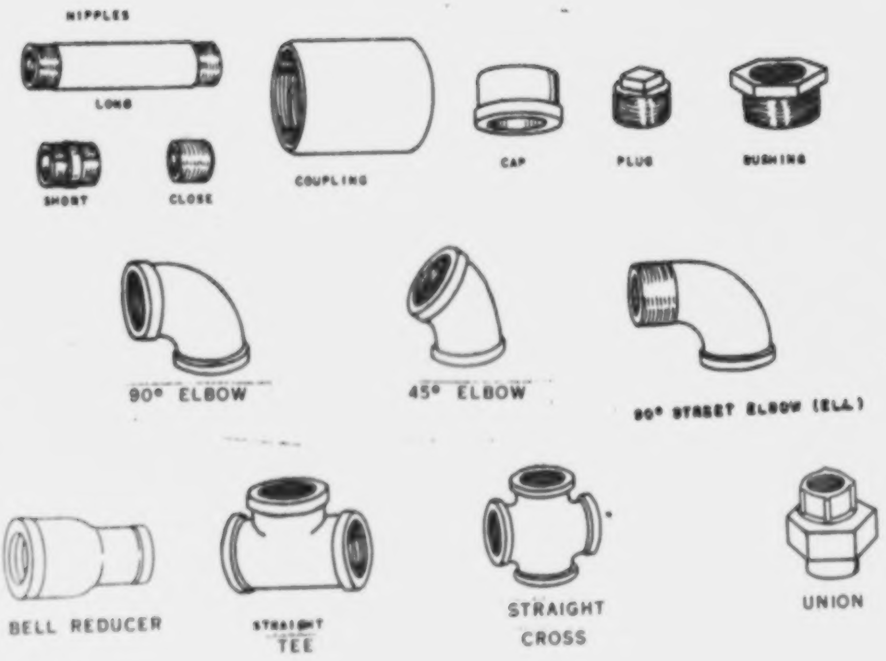

NIPPLES
LONG
SHORT
CLOSE
COUPLING
CAP
PLUG
BUSHING
90° ELBOW
45° ELBOW
90° STREET ELBOW (ELL)
BELL REDUCER
STRAIGHT TEE
STRAIGHT CROSS
UNION

Figure 3. Types of Pipe Fittings

UNIONS

____ Ground joint or machined face

____ Two female threads

____ Eases removing or installing a section of pipe or equipment

COUPLINGS

____ Female threads

____ Joins straight runs of pipe

____ Straight or plain coupling

  ____ Furnished with each length of pipe

  ____ Serves as a thread protector

NIPPLES

____ A piece of pipe less than 12" long, threaded on both ends

____ Close nipple (all-thread)

  ____ Threaded full length

____ Short nipple (shoulder)

  ____ Threaded both ends with a shoulder between

____ Long nipples

  ____ Two to twelve inches long

____ Nipples are used where short pieces of extensions of pipe are required

PIPE PLUG

____ Male thread on one end only

____ Square or hexagon head

____ Used to close off an opening in a valve or fitting

PIPE CAP

____ One female thread

____ Used to close off an opening on a piece of threaded pipe

REDUCERS

____ Bushing

  ____ One female and one male thread

  ____ Used to reduce size of an opening in a valve or fitting

  ____ Read largest male thread end first

____ Bell reducer

____ Two female threads

____ Used to make reduction in run of pipe

## Measuring, Cutting, Reaming, Threading and Fitting Pipe

### Measuring Pipe

There are several different methods of measuring steel pipe. Among these are end-to-end measurements, center-to-center measurements and end-to-center measurements, as indicated in Figure 4. End-to-end measurement is measuring from one end of pipe to the other end including the threads. End-to-center measurements are used when a pipe has a fitting screwed on one end only.

Center-to-center measurement is from the center of the outlet on one end, along the pipe to the center of the outlet on the other end. You must always remember the length of the thread on the pipe and the center measurement of the fittings to be used must be considered when determining the length to cut a pipe.

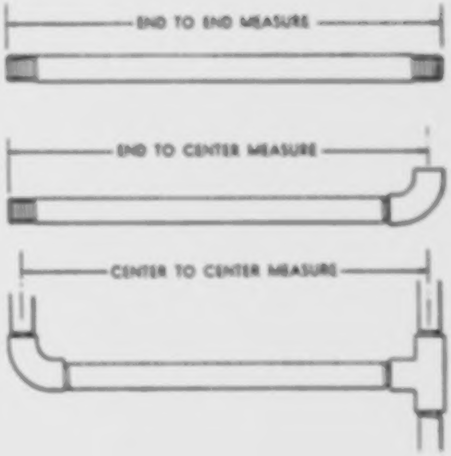


Figure 4. Determining Pipe Measurements

### Cutting Pipe by Hand

After the pipe has been measured and marked, it should be inserted into a pipe vise where it is held for the cutting operation. Figure 5. shows a piece of pipe in a vise ready to be cut with a pipe cutter. To cut pipe with a pipe cutter, open the jaws of the cutter by turning the handle counterclockwise. Then place the pipe cutter around the pipe at the mark where the cut is to be made. One revolution must be made around the pipe to make a complete cutting mark before turning the handle clockwise again to cut the pipe deeper. If this is not done, the pipe cutter will make spiral marks around the pipe instead of marking one complete circle. Figure 6 shows a pipe cutter ready to make the first turn on the pipe to be cut.

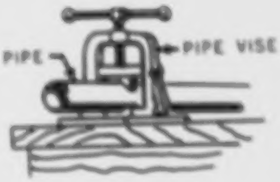


Figure 5. Pipe Vise

### Pipe Cutters

Pipe cutters, as shown in Figure 6, are available in several sizes. The size is usually indicated on the frame of the cutter. A pipe cutter with a range from 1/8 to 2 inches will handle most requirements on the job. Cutters for pipe over 2 inches in diameter usually have two handles to allow two men to rotate the cutter on the pipe. As for maintenance, keep the wheel pins and the threads on the shaft of the handle well oiled. When the cutting wheel becomes dull, you should replace it with a new wheel.

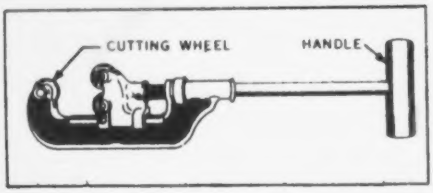


Figure 6. Pipe Cutter

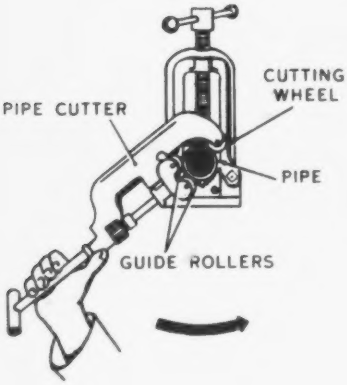


Figure 7. Cutting a Pipe with a Pipe Cutter

**WHEEL AND ROLL TYPE.** This type consists of a cutter wheel and two rollers. The wheel and roll type requires a 360-degree rotation around the pipe to cut it. After each rotation, the handle should be given a 1/4 turn.

**THREE-WHEEL TYPE.** This type of cutter has three cutting wheels. It requires only a 180-degree rotation when cutting a pipe. Three-wheel type pipe cuters can be used where a full rotation is not possible.

**COMMON SIZES OF CUTTERS.** Common sizes of cutters are:

____ No. 1 . . . . . . 1/8" to 1" pipe

____ No. 2 . . . . . . 1/8" to 2" pipe

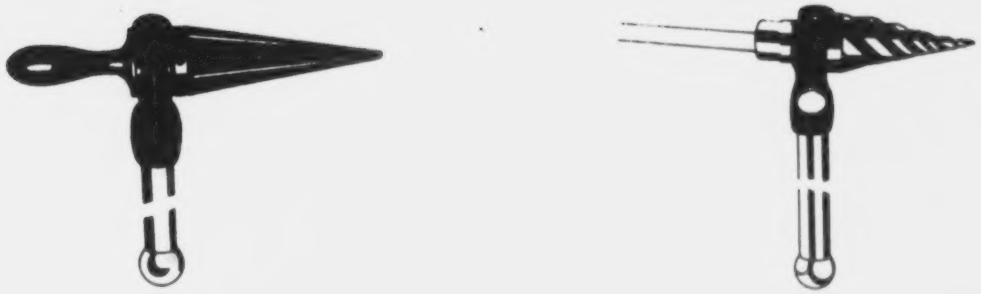
____ No. 3 . . . . . . 2" to 4" pipe

### Reaming Pipe by Hand

The burr is removed from the end of the pipe with a pipe reamer. This operation is accomplished by inserting the pipe reamer into the pipe while the pipe is still clamped in the vise. The handle on the reamer is rotated clockwise in short even strokes until the burr on the inside of the pipe has been completely removed. Two types of reamers are shown in Figure 8.

### Threading Pipe by Hand

A stock and die set of the nonadjustable ratchet type may be used to cut threads on pipe by hand. The nonadjustable ratchet dies, shown in Figure 9 can be used to cut threads on pipe from 1/8-inch to 2 inches in diameter by changing to the correct size die.



FLUTE

SPIRAL

Figure 8. Pipe Reamers

Before threading a pipe, inspect the dies to see that they are sharp and free from nicks and wear. Next, insert the pipe into the vise, place the round guide end of the pipe die stock on the pipe as shown in Figure 10 and oil the end of the pipe. Push the pipe dies against the pipe with the heel of the hand. Exert considerable pressure with the heel of the hand against the pipe die stock and take three or four short clockwise strokes, with the handle of the die stock, to start the thread cutting operation. After the dies have started, continue with clockwise strokes on the handle, as shown in Figure 11, with an even and steady pressure reverse the rotation after each three threads are cut to clean the dies, until approximately two threads project beyond the head of the die.

NOTE: To cut clean threads for watertight and airtight joints, and to ensure long life, the pipe threading dies must be oiled after each stroke with a good grade of pipe thread cutting oil. The oil prevents overheating and chipping of the dies and marring of the threads.

When the proper number of threads is cut on the pipe, reverse the ratchet on the die stock for counterclockwise operation and make several short motions backward with the handle of the stock to loosen the burrs which are inside the dies. Continue to turn the handle of the stock counterclockwise until the dies are free of the threads.

CAUTION: Many mechanics have a habit of spinning the pipe die stock rapidly to speed the removal of the dies from the pipe. While this may not be injurious to the pipe thread, extreme care must be exercised when spinning the stock to prevent it from striking the legs of the vise or causing an injury to the mechanic.

PIPE WRENCH. The pipe wrenches range in size from 6 to 60 inches. The offset wrench may be as long as 36 inches. (See Figure 12.) Pipe wrenches are used for turning pipe and round rod. Pipe wrenches should not be used on nuts, bolts, and smooth fittings. The size of these wrenches is designated by their overall length. For example, an 18-inch wrench has a handle of 1-1/2 feet long and handles pipe up to 2 inches in diameter.

MONKEY WRENCH. The monkey wrenches are used on smooth, flat fittings. Extra care must be used when working with these wrenches because of the wrench slipping off the fitting. Ensure a firm grip, and a good center of balance of your body is maintained when working with these wrenches. Monkey wrenches are made in two sizes and inches.

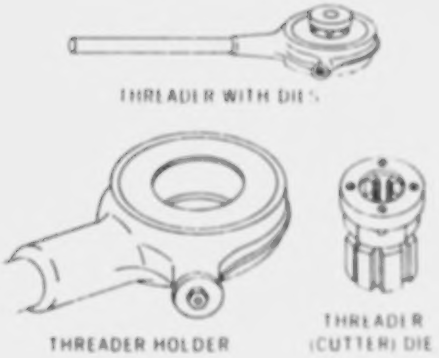

THREADER WITH DIES
THREADER HOLDER
THREADER (CUTTER) DIE

Figure 9. Nonadjustable Pipe Dies and Stock

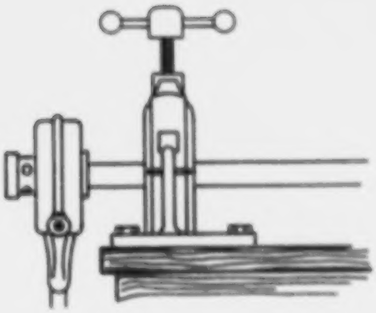


Figure 10. Placing Die Stock on Pipe

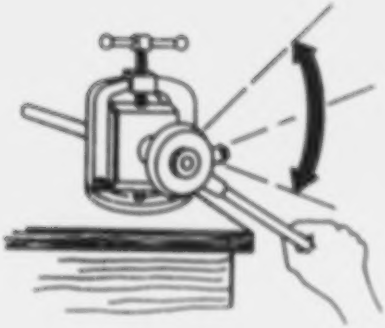


Figure 11. Threading Pipe with a Ratchet Die

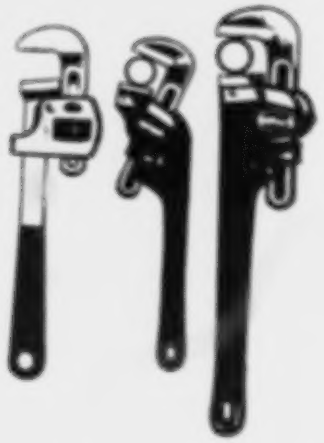


Figure 12. Pipe Wrenches

When using a pipe wrench be sure that the teeth on the jaws are clean and sharp. When the teeth become dull, they can be sharpened with a file. When they become worn out, they can be replaced by inserting a new hook jaw and a heel jaw.

The housing or main body of the wrench is made very strong and will stand tremendous strain, but DO NOT use a pipe extension on the handle; use a larger wrench. Only a pipe wrench that is in good condition should be used. If you cannot get parts, the wrench should be taken out of service immediately. Keep the threads on the hook jaw and nut cleaned and oiled.

NOTE: Never use pipe wrenches on square or hexagon shaped objects.

Joining Threaded Pipe

Before assembling a section of pipe with a fitting, clean chips with dirt from the threads of both items with a stiff bristle or wire brush. Then inspect the threads to determine that they are clean and properly cut. Coat the male threads of the pipe evenly with pipe-joint compound or, if this is not available, white lead may be used. Figure 13 illustrates the application of pipe compound to a pipe. Start the fitting on the male thread of the pipe by hand, exercising care not to cross the threads. Apply a pipe wrench to the fitting and tighten it on the pipe until the joint is made up to the desired degree of tightness. The pipe wrench should be placed on the shoulder of the fitting which is on the end of the fitting being connected. If the wrench is applied to any other part of the fitting, distortion of the fitting may be caused and result in a leaking joint. Generally, two wrenches are needed to assemble pipe, one on the pipe and the other on the fitting (see Figure 14.).

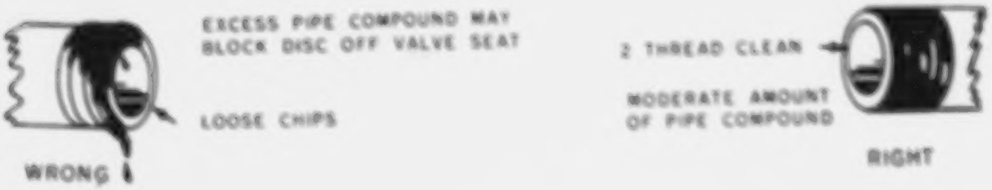

EXCESS PIPE COMPOUND MAY BLOCK DISC OFF VALVE SEAT
LOOSE CHIPS
WRONG
2 THREAD CLEAN
MODERATE AMOUNT OF PIPE COMPOUND
RIGHT

Figure 13. Applying Pipe Compound to a Pipe

NOTE: There are several reasons for using pipe joint compounds. It may be used as a sealing agent, a corrosive protective agent or as an anti-seize compound. The anti-seize compound is used in case the joints must later be disassembled.

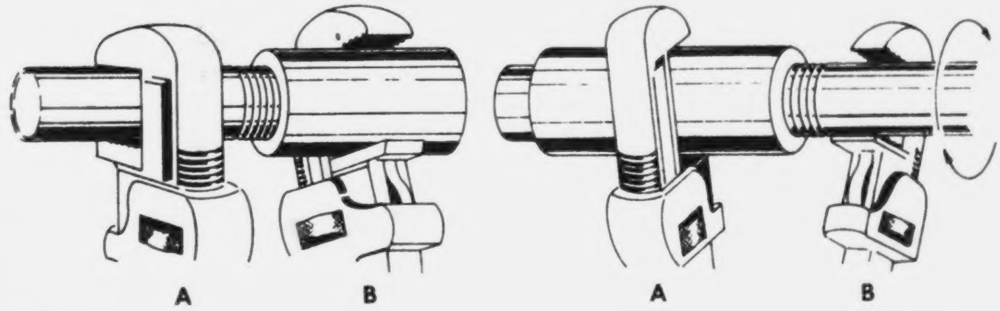


Figure 14. Using Two Wrenches

## Valves Used in Heating Systems

Due to the number of valves which appear in heating installations, a thorough knowledge of the maintenance and repair of these valves is necessary. Inspection of any valve consists of close examination for visible wear and breakage. Valves are used in piping systems to regulate or control flow in the pipes.

### Identification of Valves

Following information is to help you to identify valves as to size, threads and markings.

SIZE. Measured by inside diameter.

THREADS. Two female threads.

BODY MARKINGS

____ WOG - Water, oil or gas

____ WSP - Working steam pressure

____ Safety precautions to be observed when installing valves

  ____ Unmarked valves (brass)

  ____ Can be used for maximum of 125# psi or 450° F temperature

____ Some valves have arrows stamped in the body, install in the proper direction.

The following information will help you identify valves already installed in the piping system. The length of valve bonnet will determine if valve is a rising stem or non-rising stem. Short bonnet indicates a non-rising stem, long bonnet indicates rising stem. The shape of valve body will determine if valve is a gate or a globe valve. Valves with flat sides are gate valves; valves with rounded sides are globe valves.

### Types of Valves, Their Repair and Maintenance

GATE VALVE. A gate valve is one of the most used valves. A gate valve is illustrated in Figure 15 and contains a sliding disc which moves vertically and seats between and against two seats to shut off the flow.

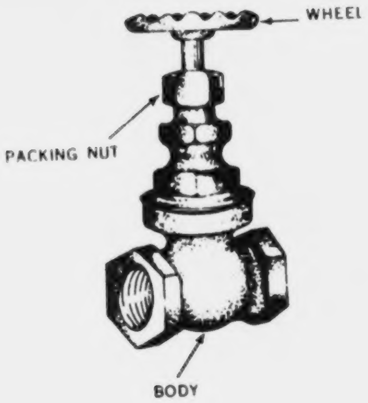

WHEEL
PACKING NUT
BODY

Figure 15. Gate Valve

A threaded stem is used to lift or lower the disc, to open or close the valve. The volume of flow through the valve, however, is not in direct relation to the number of turns of the handwheel. Gate valves have either a single, solid wedge-shaped disc or valves may be provided with either rising stems or nonrising stems. See figures 16 and 17. Gate valves are used for services where the valve is kept either fully opened or fully closed. To prevent binding, this type valve should never be overtightened.

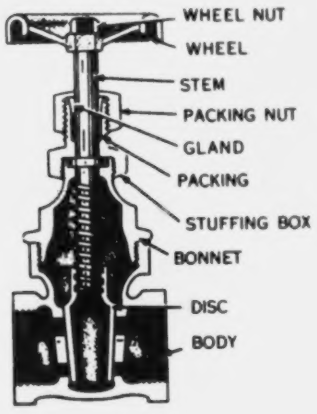

WHEEL NUT
WHEEL
STEM
PACKING NUT
GLAND
PACKING
STUFFING BOX
BONNET
DISC
BODY

Figure 16. Nonrising Steam, Wedge Disc Gate Valve

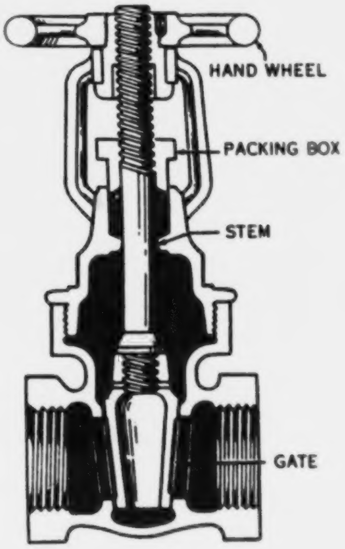

HAND WHEEL
PACKING BOX
STEM
GATE

Figure 17. Rising Stem, Wedge Disc Gate Valve

Gate valve leaks may occur at the valve seat, around the stuffing box and at the body-bonnet joint. Repairs should be made at the first sign of a leak. Tightening a leaking joint will often correct the condition. Other remedies are the replacement of gaskets or renewable parts, repacking stuffing boxes, and regrinding valve seats.

The stuffing box holds the packing which seals the bonnet against leaks around the stem (See Figure 16 and 17). Pressure is applied on the packing by a packing nut or gland flange, which bears on a gland in the stuffing box. Packing wears in direct relation to service condition. It loses life with age, but wear is mainly due to rising and turning motion of the valve stem. Generally, packing lasts a long time and needs little attention. Stuffing box leaks can usually be stopped by tightening down on the packing nut or gland of the valve. On bolted glands, care must be exercised to tighten the bolts evenly, since cocking will bind the stem. If a stuffing box leak cannot be remedied by tightening the packing nut, the packing must be replaced.

Inability to close a valve tightly is an indication of a valve seat leak. Trouble of this sort is usually caused by scale, metal particles or other foreign matter in a line. Occasionally, it comes from a cut in the seat or disc caused by a high velocity flow of fluid through a limited area where the valve is not fully closed. When valve seat leaks occur, the seat and disc may be repaired provided the damage is not too extensive. If the disc is made of soft metal, it may be refaced (lapped) by using a mixture of oil and lapping compound on the machined surface as an abrasive to replace the disc. By using a figure eight motion, the two surfaces are lapped thru to each other.

Gate valves are available in many styles and sizes. They are designed to meet all needs from low pressures to high pressures. They are manufactured to receive screwed, welded, sweated and flanged piping.

The larger the valve, the more complex the repair will become.

GLOBE VALVE. A globe valve, as ilustrated in Figure 18, has a horizontal interior partition which shuts off the inlet from the outlet, except through an opening in the partition (See Figures 19 and 20). The lower end of the valve stem holds a replacement fiber or metal disc shaped and fitted to close the hole in the horizontal partition. The valve is closed by turning the handwheel clockwise until the disc presses firmly on the opening. The volume of flow through globe valves is roughly proportionate to the number of turns of the handwheel. Globe valves may be provided with either flat or beveled seats, depending upon the type of disc.

The plug-type disc consists of a tapered plug which provides a wide area of seating contact. This type of valve seating provides a very effective means of flow control and offers high resistance to the cutting effects of dirt, scale and other foreign matter.

A conventional disc, which forms a relatively narrow contact with the valve seat, provides a more positive and higher pressure contact than a wide seat. The thin line contact breaks down hard deposits that form on valve seats and insures a pressure-tight closure. The conventional disc is made in several seating styles, such as flat seating, ball seating, and with seating surfaces having varying degrees of taper (see Figure 19).

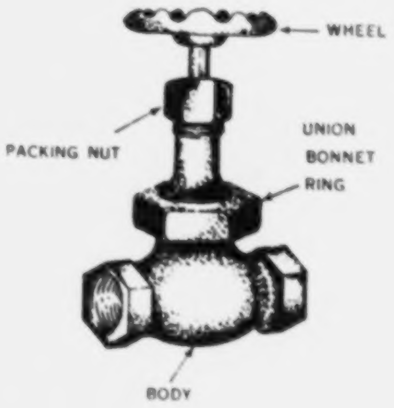


Figure 18. Globe Valve

A composition disc operates on the principle of a cap. Its face seats against or into the valve opening. Most composition discs consist of three parts: a metal disc holder, the disc itself, and a retainer nut. The main advantage of a composition disc is the variety of disc materials available for individual services such as air, hot or cold water, gas, oil, gasoline, and other applications. Globe valve leaks occur at the same points as they do on gate valves. (See Figure 20.)

When valve seat leaks are found in plug type or conventional discs, the valves can be repaired by removing the disc, inserting a washer under it, then lapping to make a snug fit.

Valve seat leaks in composition disc globe valves are corrected by replacement of the disc. If the seat is severely pitted, the entire valve should be replaced.

Stuffing box leaks are corrected in the same manner as for gate valves. If tightening the packing nut does not stop the leak, replace the packing.

CHECK VALVES. A check valve as illustrated in Figure 21 is used when it is necessary to control the flow in one direction only. Fluid flow in the proper direction keeps the valves open and reversal flow closes them automatically (see Figures 22 and 23). For installation purposes, most check valves are marked to indicate the inlet opening or direction of flow. There are two basic types of check valves: swing check valves and lift check valves. Each type has several variations that make them suitable for specific plumbing installations. A swing check valve should be used in conjunction with a gate valve and a lift check valve with a globe valve.

Swing check valves contain a hinged disc which seats against a machined seat in the tilted bridge wall opening of the valve body (See Figure 22). This disc swings freely on its hinge pin in an arc from a fully closed position to one parallel with the flow. The fluid or gas in the pipeline enters below the disc. Line pressure overcomes the weight of the disc and raises it, permitting a continuous flow. If the flow is reversed or back-pressure builds up, this pressure is exerted against the disc, forcing it to close and stop the flow.

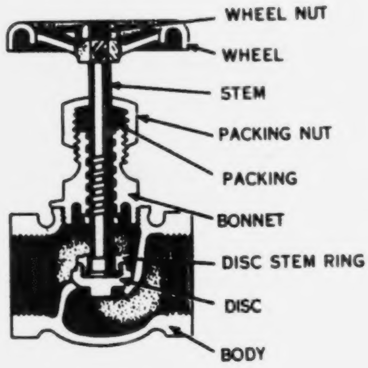


Figure 19, Globe Valve, Conventional Disc

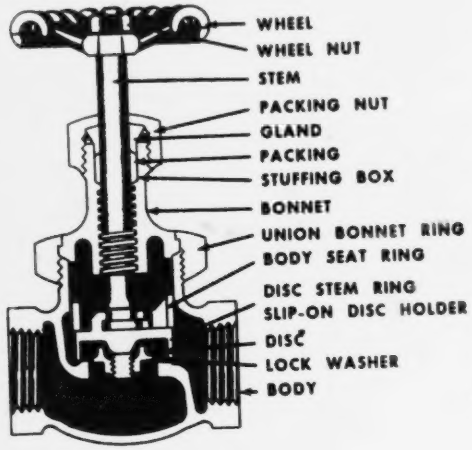


Figure 20. Globe Valve, Composition Disc

Lift check valves contain a disc which seats on a horizontal bridge wall in the valve body (see Figure 23). The disc is raised from its seat by the pressure of the fluid flow and moves vertically to open. To insure proper seating and rising, the disc is provided with short guides, which are usually above and below the disc. The valve is closed by backflow, or by gravity when there is no flow.

Check valve leaks occur due to sticking parts or pitted valve seats. To operate properly, the valve disc must fit firmly in its seat. Valve seats can be reground with a reseating tool or by lapping.

ANGLE GLOBE VALVES. Angle globe valves are similar in construction and operation to globe valves, except that the valve outlet is at an angle of 90 degrees to the inlet. The same repair procedures as used on globe valves should be followed (see Figure 24). This type of valve is used on radiators or convectors.

PLUG VALVES. Plug valves have a circular tapered, ground plug fitting, a tapered hole or seat (see Figure 25). An opening through the plug permits the passage of fluid through the valve when the opening is aligned with the pipeline. Plug valves may be completely and quickly opened by a one-quarter turn of the handle and do not have soft packing which tends to wear.

Leaks in plug valves can usually be corrected by cleaning or by adding a special lubricant. The lubricant makes it easier to turn the valve and also seals the points where the plug does not seat perfectly. If the valve seat is severely pitted, the entire valve must be replaced.

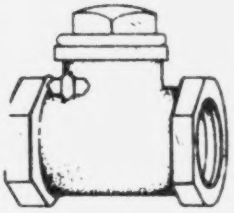


Figure 21. Check Valve

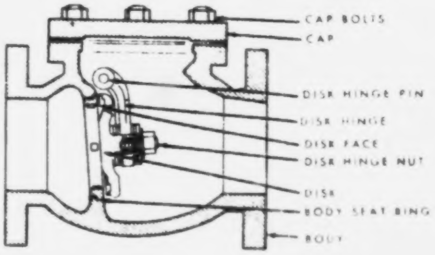

CAP BOLTS
CAP
DISK HINGE PIN
DISK HINGE
DISK FACE
DISK HINGE NUT
DISK
BODY SEAT RING
BODY

Figure 22. Swing Check Valve With Brass Disc

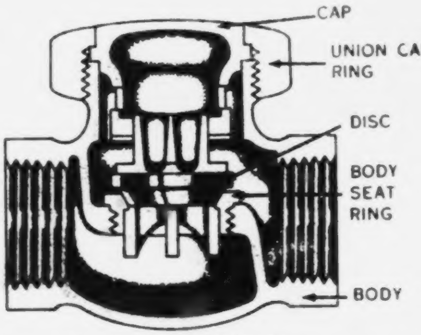

CAP
UNION CAP RING
DISC
BODY SEAT RING
BODY

Figure 23. Lift Check Valve With Composition Disc

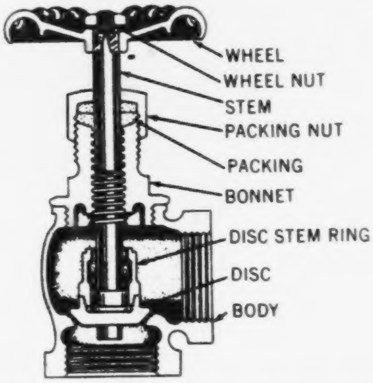

WHEEL
WHEEL NUT
STEM
PACKING NUT
PACKING
BONNET
DISC STEM RING
DISC
BODY

Figure 24. Angle Globe Valve

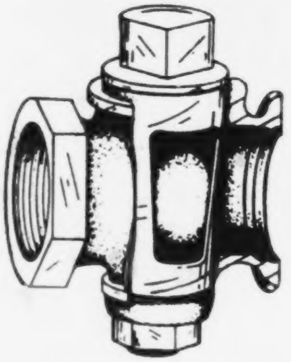


Figure 25. Plug Valve

SUMMARY

Cutting, reaming and threading pipe are common operations performed daily by heating specialists. These operations may be accomplished either by hand or with power tools.

Pipe may be cut either by use of a standard pipe cutter or a hacksaw. Cutting pipe with a pipe cutter is preferred method. Cutting with a pipe cutter will cause a burr to form on the inside of the pipe. This burr must be removed since it hinders the flow of liquids and causes stoppages. The reamer is a fluted unit which is placed in the end of the pipe and turned clockwise. The turning action cuts off the burrs.

After the pipe is reamed it is ready to be threaded. Pipe may be threaded by the use of various types of threaders. Threading may be accomplished with either hand tools or power tools. The pipe must be held rigidly in a pipe vise and the dies properly placed on the pipe and turned clockwise to make a good thread. Plenty of cutting oil should be used during the threading operation to keep the die segments cool and prevent them from chipping. A sufficient number of threads have been cut on the pipe when about two threads extend beyond the die segments.

To obtain a tight threaded joint, it is important that the threads be clean and in good condition. If the pipe or fittings have been exposed to the weather or banged around, see that the threads are checked very carefully. If necessary, run a tap in or die over the threads to redress those that are damaged.

Cleaning the threads by brushing is a good start in making this joint after you have secured the pipe in a vise. Next, smear a good thread lubricant on the male threads. Use red lead or white lead for water pipes, and mixed powdered graphite and oil for steam pipes. This "pipe dope" is not used inside the fitting.

Start the fitting by hand and turn it up as far as you feel it will go. Then tighten it with a pipe wrench. Do not use a hickey, or oversized wrench, or too much pull. Not all of the male threads need go into the joint. If all the threads are used, the wedging action of the tapered thread may cause the fittings to split.

Experience is the best teacher in determining how tight a joint should be. Usually, you will have two or three unused threads on a properly threaded pipe. If these steps are followed, and the threads have been made properly, the joint will be tight enough to withstand the pressure for which the pipe and fittings were made.

QUESTIONS:

1. What is the most common type of pipe used in the heating field?

2. What type pipe should be used for natural gas lines?

3. What are the most common sizes of pipe used?

4. What fitting picks up a branch line at a 90-degree angle?

5. What fitting is used to join straight runs of pipe?

6. What is a piece of pipe less than 12" long called?

7. What is the maximum pressure that an unmarked valve may be used with?

8. How should you prevent binding of a gate valve?

9. What must be done to a globe valve if the seat of a composition disc type is severely pitted?

10. What are the two basic types of check valves?

11. Angle glove valves are repaired in the same manner as what other type of valve?

12. How do you measure pipe length?

REFERENCES

1. AFM 85-20, Plumbing.

HANDLING

Reinforced thermosetting pipe must be handled with a reasonable amount of care, because of damage to pipe wall and fittings.

The following recommendations should be observed in order to protect the pipe from possible damage.

TRANSPORTATION

1. Let the factory arrangement of the pipe be your guide for the correct supporting and spacing in rearranging for transport.

   NOTE: Don't let the pipe rest on the floor of the truck where nails, studs, and other objects might damage it.

2. Pipe should be securely fastened directly over the spacing and padding with tie downs consisting of nylon straps or manila rope.

3. Avoid extending the pipe more than 3 ft. beyond the truck or trailer bed because permanent damage can result from excessive flexing.

4. Pipe is a light load, avoid fast speed or rough roads to minimize bouncing.

LOADING AND UNLOADING

1. Pipe and fitting should never be thrown or dropped under any circumstances.

2. The pipe should be carefully loaded and unloaded one length at a time, by hand. See Table #2.

3. If the pipe is properly separated and supported, forklifts can be used. See Table #2.

TABLE 2

| PIPE DIAMETER | WEIGHT PER FOOT | WEIGHT PER 20 FT LENGTH | WEIGHT PER 42 FT LENGTH |
|---|---|---|---|
| 2 in. | 0.5 lb (0.23 kg) | 10 lb (4.5 kg) | 21 lb (9.5 kg) |
| 3 in. | 0.7 lb (0.32 kg) | 14 lb (6.4 kg) | 29 lb (13.0 kg) |
| 4 in. | 1.0 lb (0.45 kg) | 20 lb (9.1 kg) | 42 lb (19.0 kg) |
| 6 in. | 1.7 lb (0.77 kg) | 34 lb (15.0 kg) | 71 lb (32 kg) |
| 8 in. | 3.3 lb (1.5 kg) | 66 lb (30 kg) | 139 lb (63 kg) |
| 10 in. | 4.8 lb (2.1 kg) | 94 lb (43 kg) | 197 lb (89 kg) |
| 12 in. | 6.3 lb (2.9 kg) | 126 lb (57 kg) | 265 Lb (120 kg) |
| 14 in. | 8.0 lb (3.4 kg) | 148 lb (67 kg) | 311 lb (141 kg) |
| 16 in. | 0.1 lb (4.8 kg) | 212 lb (96 kg) | 445 lb (202 kg) |

STORAGE

The pipe can be stored outside for extended periods provided the following recommended storage procedures are observed.

1. Support should be spaced in 10 ft intervals and approximately 5 ft. from each end. The supports should have a minimum 4 inch wide bearing surface.

2. A pipe stack should not exceed 10 ft. in height and should have side supports or blocks to prevent rolling or slipping of the stack.

3. Tie downs should consist of nylon straps or manila rope. Avoid overtightening which may cause excessive localized deformation in the pipe.

4. If stacking directly on the ground, a leveled, soft earth surface, free of rocks or sharp objects is a must.

5. Protective end covering should be left intact until the time of installation to provide protection to the pipe ends, as well as guard against dirt or other materials entering the pipe.

6. Fittings, adhesives, and tools should be stored in the shipping boxes under cover and protected from water, mud, and extreme heat or cold.

CUTTING

1. For all cutting and tapering, the pipe must be held securely with a strap wrench, saw guide clamp assembly, or a chain vise.

2. The pipe should be cut with a fine-toothed hacksaw for 2" - 6" pipe and a power driven circular abrasive cut-off wheel for 8" - 16" pipe.

   NOTE: Protective respirators should be worn when using powered cut-off or tapering equipment.

3. The cut made on a pipe must be straight as possible to insure proper tapering. Saw guides are recommended, but when not available, a wrap around may be used to scribe or mark a cutting guideline. Maximum out-of-square tolerances are shown in Table 3.

Table 3

TAPER LENGTH/ANGLE/OUT-OF-SQUARE, 2" - 16"

| PIPE SIZE | TAPER LENGTH | TAPER ANGLE | MAXIMUM OUT-OF-SQUARE |
|---|---|---|---|
| 2 in. | 1-5/8 in. | 1-3/4° | 3/16 in. |
| 3 in. | 1-3/4 in. | 1-3/4° | 3/16 in. |
| 4 in. | 1-7/8 in. | 1-3/4° | 3/16 in. |
| 6 in. | 3 in. | 1-3/4° | 3/16 in. |
| 8 in. | 2-3/4 in. | 2° | 3/16 in. |
| 10 in. | 3-1/2 in. | 2° | 1/4 in. |
| 12 in. | 4 in. | 2° | 1/4 in. |
| 14 in. | 4-1/2 in. | 2° | 1/4 in. |
| 16 in. | 5-1/4 in. | 2° | 5/16 in. |

ADHESIVE MIXING

Mixing instructions are packaged with each kit. Avoid direct contact with skin or eyes. Use soap and water to wash off any of these materials from skin. If any of the liquid gets into eyes, flush immediately with water, not solvent, get medical aid immediately.

STEPS

1. In cold weather, warming the resin to 60° F. is recommended for best results.

2. Empty all the hardener into the can of resin. Never try to split a kit. Use a wooden spatula until all streaks are gone. Adhesive has a smooth uniform pink color when mixed. Be sure to mix all resin from lid and from under the upper lip of can for best results. Avoid stirring too vigorously; may cause the hardener to splash out or result in excessive air entrapment.

ADHESIVE WORK LIFE

The working life (Pot Life) of adhesives are shown in Table 4. Pot Life is the time it takes for the adhesive to harden (Based on 75° F.). It is measured from the time the hardener and resin are first mixed. Heat shortens the Pot Life, so keep adhesive kits cool to extend the Pot Life. To prolong the Pot Life, pour and spread out onto aluminum foil (spreading cools the adhesive, slows the chemical reaction, and prolongs the useful life of the adhesive).

## ADHESIVES

Adhesives used in the joining of the pipe comes in two parts systems. Each kit contains resin, hardener, instructions, and (except for 1 oz. kits) cleaning solvent, towels, mixing stick, and an application brush.

Each kit has a specific number of bonds each kit will make for each respective pipe size. Table 4 is based on the quantity of adhesive required by an experienced crew working at a temperature of 70° F.

### TABLE 4

### BONDS PER ADHESIVE KIT

| KIT SIZE NOMINAL PIPE SIZE | 1.0 oz. BONDS PER KIT | 6.8 oz. BONDS PER KIT | 10.0 oz. BONDS PER KIT |
|---|---|---|---|
| 2 in. | 2 | 14 | -- |
| 3 in. | 1 | 9 | 14 |
| 4 in. | 1 | 7 | 9 |
| 6 in. | - | 3 | 4 |
| 8 in. | - | 2 | 3 |
| 10 in. | - | 2 | 3 |
| 12 in. | - | 2 | 3 |
| 14 in. | - | 1 | 2 |
| 16 in. | - | 1 | 2 |

NOTE: - Not enough to complete job or waste.

### TABLE 5

### ADHESIVE WORKING LIFE/TIME TO CURE*

| TEMPERATURE | 60° F.** (16°c) | 70° F. (21°c) | 85° F. (29°c) | 100° F. (38°c) | 120° F. (49°c) | 150° F. (66°c) |
|---|---|---|---|---|---|---|
| POT LIFE | 20 min. | 25 min. | 15 min. | 10 min. | 8 min. | ---- |
| TIME TO CURE | 12 hr.<br>(8 hr.) | 5 hr.<br>(3 hr.) | 4 hr.<br>(2 hr.) | 3 hr.<br>(1-1/2 hr.) | 2-1/2 hr.<br>(1-1/2 hr.) | 1-1/2 hr.<br>(45 min.) |

*Time shown in parentheses indicates when sufficient care will have been obtained to permit moving of the assembly.

**At temperatures below 60° F., a heat assist method must be utilized to force cure.

### HEAT ASSIST ADHESIVE CURE METHODS

Heat generating chemical package using two or more chemicals when mixed and water added causes a chemical reaction which gives off heat. This method increases the temperature and allows the pipe to cure.

Heat blanket is a silicone rubber heater that is thin, flexible, lightweight, and corrosion resistant. It provides for rapid curing of the adhesive. If the blanket is exposed to an extremely cold or windy environment, the blanket should be wrapped with aluminum foil or fiberglass insulation. The heat blanket is available in three sizes. The heat blanket has a wattage of 2 watts/sq. in., and will reach a maximum temperature or 240° F. See Table 5.

## TABLE 6

## HEAT BLANKET SIZES

| SIZE | DIMENSIONS | NOMINAL PIPE DIAMETER |
|---|---|---|
| 1 | 4.5" x 16 | 1", 3", 4" |
| 11 | 5" x 36.5" | 6", 8", 10" |
| 111 | 6" x 55" | 12", 14", 16" |

## SUMMARY

Reinforced thermosetting resin pipe is easy to damage so it is important to learn how to handle, load, and store it. When cutting and tapering resin pipe, care must be used because of the close tolerances needed for a good bond. When using adhesives, time is of the utmost importance as well as the mixing and application of it. When working in adverse weather conditions alternative heat assisted cure methods must be used.

## QUESTIONS

1. In handling resin pipe, whose recommendation do we follow? ____________________

   ________________________________________

2. What is the maximum height you can stack resin pipe? ____________________

3. How many bonds can you get with a 6.8 oz. adhesive kit using 6 in. resin pipe?

   ________________________________________

4. What color does the adhesive turn when properly mixed? ____________________

5. What factor affects the Pot Life of the adhesive? ____________________

   ________________________________________

6. Name the two heat assist adhesive cure methods?

   1) ________________________________________

   2) ________________________________________

7. What is the angle of taper for a 2" pipe? ____________________

8. What is the nominal weight of a 2" pipe 20' long? ____________________

9. How far apart should you place the supports? ____________________ and approximately ____________________.

10. The pipe should be cut by ____________________ for 2" - 6" pipe and a ____________________ for 8" - 16" pipe.

## BACKFLOW/CROSS-CONNECTION

This section is designed to help you identify the facts about Backflow/Cross-Connection. By thorough study you will learn how the Backflow/Cross-Connection devices and controls help us.

### INTRODUCTION

The ever expanding water demands by industrial ad commercial operations, plus the desirability of auxiliary fire protection, are increasing the possibilities of cross-connecting potable water systems to contaminated sources.

Many contaminants and pollutants have no odor or color and can enter the public water supply undetected. A contaminant is a toxic substance in the potable water supply - one that could affect the health of life of the consumer. Examples are antifreeze and sewage. A pollutant is a nontoxic substance in the potable water supply that could create a nuisance or be esthetically objectionable. Examples are sugar and wine. What can happen with cross-connection could be costly. In 1969, Holy Cross College had to cancel its team's football schedule because the entire team had contracted hepatitis.

### INFORMATION

o BACKFLOW - The flow of water or another liquid, mixture, or substance into the distributing pipes of a potable supply of water from any source or sources other than the intended source.

In Cincinnati, Ohio several years ago at a winery, the wine backed up into the potable water supply due to unusual circumstances.

o CROSS-CONNECTION - A physical arrangement in which a public potable water supply is connected, directly or indirectly, with any non-potable or unapproved water system.

A typical residential cross-connection is when a bucket of soapy water is cross-connected to the potable water system by a garden hose.

A typical industrial cross-connection is between a primary and secondary water supply, for example, large industries use the potable water supply for drinking water, and they frequently drill their own wells or use nearby surface sources for their process water supplies. These water systems should be separated and protected.

o BACK PRESSURE - Back Pressure is caused when a potable system is connected to a nonpotable supply operating at a higher pressure by means of a pump, boiler, or elevated tank.

A typical back pressure condition could happen when a typical ocean-going ship at the pier uses its on-board pumps to pump harbor water through the ship for various reasons. A ship's pump pressure could be greater than the potable water supply pressure and harbor water would be pumped back into the potable water supply. Concentrated efforts since the 1930's have almost eliminated this problem.

o BACK-SIPHONAGE - This results from negative or reduced pressure in the supply piping.

Some of the causes of back-siphonage are:

1. Undersized piping, either in mains or service lines.
2. Water line breaks or line repairs that lower the pressure upstream of the service point.
3. Reduced pressure on the suction side of booster pumps within system.
4. Lowered main pressure due to high flow rates for fire fighting or for line flushing.

An example of back-siphonage happened in a residential area. A car hit a fire hydrant, causing an excessive flow of water. In the house was an old bathtub [illegible] with a running submerged inlet. With the great flow of water the pressure dropped and caused the used bath water to be distributed throughout the house and into the city water.

SUMMARY

Water and health officials who are voicing their concerns about the hazards of cross-connections are growing in strength and numbers. The problem is a serious one facing the water industry today as emphasized by reports of contaminated drinking water and the spread of waterborn illnesses.

QUESTIONS

1. What is a contaminant? ________________________________________

2. The flow of water or another liquid, mixture, or substance into the distribution pipes of a potable supply of water from any source or sources other than the

   intended source is ________________________________.

3. Describe cross-connection. ________________________________________

   ________________________________________________________________.

4. Name the two types of backflow and explain each.

   1. ____________________________________________________________.

   2. ____________________________________________________________

5. What is a pollutant? ________________________________________

   ________________________________________________________________.

6. Describe back-siphonage. ________________________________________

   ________________________________________________________________

## IDENTIFICATION OF HAZARDOUS PIPING

This section of instruction is designed to help you identify the facts about hazardous piping. By studying military standard 101B; 3 December 1970; will give you the knowledge to identify the color code for hazardous piping.

INTRODUCTION

We as heating systems specialist must have a knowledge of what is being conveyed in our piping systems which run through our heating plants. We must know which one carries what, so that's why we have each pipe identifed by color, content, and symbols. We don't want cold water added to steam boiler until the cold water is heated. This alone could cause the boiler to explode.

INFORMATION

COLOR

The color assigred in this standard shall conform in hue and chroma to the requirements identified by number in FED. STD., No. 59$^{5}$ No change shall be made in the assigned colors without prior approval of the prescribing activity of this standard.

## WARNING COLORS

The following colors are assigned for use as both primary and secondary warnings:

a. YELLOW, NO. 13655 - FLAMMABLE MATERIALS

b. BROWN, NO. 10080 - TOXIC AND POISONOUS MATERIALS

c. BLUE, NO 15102 - ANESTHETICS AND HARMFUL MATERIALS

d. GREEN, NO. 14187 - OXIDIZING MATERIALS

e. GRAY, No. 16187 - PHYSICALLY DANGEROUS MATERIALS

f. RED, NO. 11105 - FIRE PROTECTION MATERIALS.

## COLORS HAVING NO SIGNIFICANT MEANING

BLACK NO. 17088 and WHITE NO. 17875. These colors are assigned, without significant meaning, for general use where specified in this standard except as follows: Water-piping systems containing water suitable for human consumption and installed for this purpose shall be painted WHITE, NO. 17875, throughout or shall be painted to match surroundings when not in conflict with other color designations in this standard.

## CLASSIFICATION OF MATERIAL IN PIPING SYSTEMS

The classifications of materials in a piping system shall be as specified in Table 7. When no secondary color warning is specified, an arrow may be used and painted with the same color as the primary warning or black or white, as preferred.

NOTE: N.O.S. refers to materials "NOT OTHERWISE SPECIFIED."

TABLE 7

CLASSIFICATION OF MATERIALS IN PIPING SYSTEM

| MATERIAL | PRIMARY COLOR WARNING | SECONDARY COLOR WARNING |
|---|---|---|
| AIR, COMPRESSED | GRAY | GREEN |
| FUEL OIL, N.O.S. | YELLOW | ----- |
| MANUFACTURED GAS | YELLOW | BROWN |
| NAUTRAL GAS | YELLOW | BROWN |
| STEAM | GRAY | ----- |
| WATER, OVER 50 PSIG/ 150° F. | GRAY | ----- |
| WATER, POTABLE | WHITE | ----- |

## SUMMARY

It is of the utmost importance that you as heating system specialists learn as much as possible about the color code and the colors you will come into contact with on your job.

This knowledge will help you to perform your job better and keep you safe. It may save your life!

QUESTIONS:

1. What is Military Standard 101B? ______________________________

______________________________________________________________

2. What must each color conform to in Federal Standard #595? ____________

______________________________________________________________

3. In the color code, yellow stands for ______________________________.

4. Gray stands for ______________________________________________.

5. What is the primary color for natural gas? __________________________

6. Water suitable for human consumption, (Potable), is coded by what primary color?

______________________________________________________________

## Theory of Prints, Symbols and Scales

### Theory of Prints

When performing your duties you will encounter numerous references to plans, drawings, prints or blueprints. Learning to read and interpret drawings is one of the requirements of civil engineering personnel. Blueprint reading is a task in which there is no substitute for experience. Learning to use prints involves knowing the purpose of prints, knowing the types of prints, how to handle prints, understanding the alphabet of lines, explanation of lines, projected views, and symbols and their uses.

### Types of Prints

BLUEPRINTS. The simplest and most generally used copying process for making prints that you will use are blueprints. They are made by placing a sheet of special translucent tracing paper over the drawing in close surface contact with each other, then exposed to a strong light, in a printing frame or machine made for this purpose. This process produces a print with a blue background and white lines.

### Handling of Prints

Prints can be much more useful if properly cared for by the user. Smudging, tearing, coffee cup rings, etc., should certainly be avoided. Careless handling of project drawings may cause costly errors.

Normally, each shop has drawings of existing facilities with additional equipment or new construction features designated for the purpose of maintaining system changes. They are usually kept in racks or tubes for easy access. If drawings become damaged or unreadable, copies may be obtained from the engineering section.

The "on-the-job" handling of prints is very important since smudging and tearing usually occur here. The "thumbing space" left on the outer edge of the print is designed to prevent this. Greasy and dirty fingers, or instruments, should never be used to aid in tracing lines. If you have trouble following lines on the drawing with your eye, the use of a clean, nonmarking, dull instrument should be used. In the event you have misplaced your tracing aid, large nails are usually available and work rather nicely. Screwdrivers and other sharp tools should be avoided. Never depend on readings from a print when that reading has been obscured by a smudge or tear.

## Identification of Lines

The most basic symbol and the one requiring the greatest understanding is the use of lines. The thickness of the line and the configuration used, must be understood to be able to use a blueprint or drawing properly.

The American Standard Association (ASA) has established standards for the width of lines used on drawings. The Association approved the exclusion of heavy lines on pencil drawings. However, heavy (wide lines) are still used on ink drawings. Of course, the width of line used on the tracing will be the same as appears on the prints made from the tracing. In reference to drawings, the words "weight" and "width" have the same meaning.

On drawings, the heavier lines will be used for the border, the medium lines will be used for the object, and the finer lines will be used for centerlines and dimension lines. The following explanations will aid you in identifying lines used on drawings.

BORDERLINE( ━━━━━━━━ ). The borderline is the heavy line around the outer edge of the print. It informs the reader that the intended illustration is complete within these borders. Exactly what the illustration is supposed to be is noted on the legend in the lower right corner along with other necessary reference information.

OBJECT LINE (VISIBLE LINE) (————————). The object or visible line outlines the specific item illustrated by the draftsman. It is a medium weight line which shows the shape of the object to the reader. It is used to outline buildings, partitions within the structure, piping, conduit, etc. It is the most important line on the print because it forms the object to which we are referring.

CENTERLINE (—————— —— ————). The centerline is used when it is necessary for the reader to use the center of an object as reference. Consult your symbols and become thoroughly familiar with it; whenever it is used, it usually adds great significance to the drawing.

EXTENSION AND DIMENSION LINES (<————    ————>). Extension lines are used to bring meaning to dimension lines. The centerlines and extension serve as stops for dimension lines. The extension lines do not touch the object, but start about 1/16 of an inch from the object line and extend about 1/8 of an inch beyond the dimension arrow. In instances where the dimension must be located inside the object, the object lines serve as stops.

CUTTING PLANE LINES (↑___ ___ ___ ___↑). This is merely a line symbol to given accuracy to the reader as to the view taken by the draftsman (very useful in the machine tool business, but used less in construction drawing).

SECTION LINING (SHADING). Used on detail drawings to indicate material to be used. They also may be used to show a cutaway of an object. (Refer to Figure 26 )

BREAK LINES (——⋀————⋀——). In drawing a detail of piping, shafting, etc., it is usually drawn with break lines. Uses of conventional break lines are illustrated in Figure 27.

HIDDEN LINES. Hidden lines are medium lines which consist of short dashes evenly spaced (--------------) that show hidden features of the object.

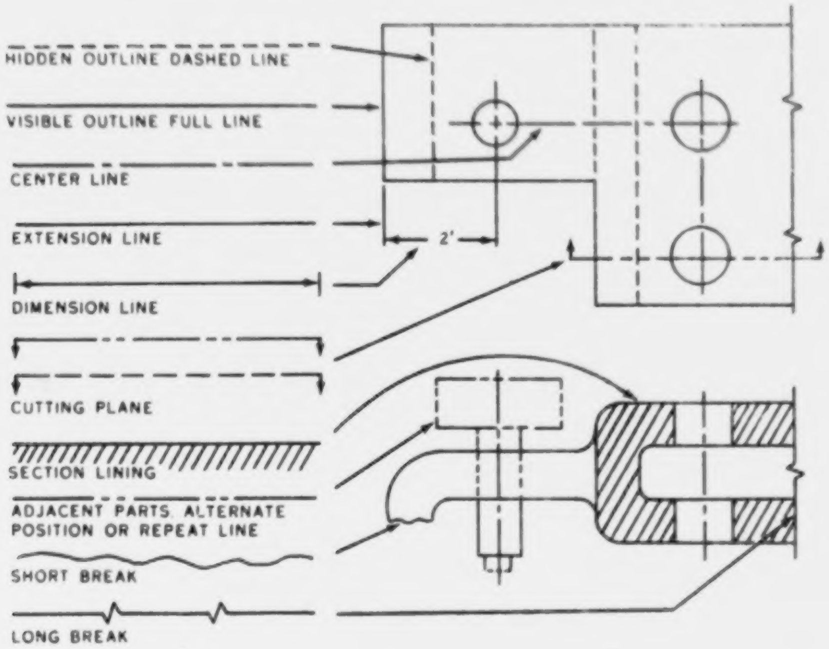

HIDDEN OUTLINE DASHED LINE
VISIBLE OUTLINE FULL LINE
CENTER LINE
EXTENSION LINE
2'
DIMENSION LINE
CUTTING PLANE
SECTION LINING
ADJACENT PARTS ALTERNATE POSITION OR REPEAT LINE
SHORT BREAK
LONG BREAK

Figure 26 Line Symbols

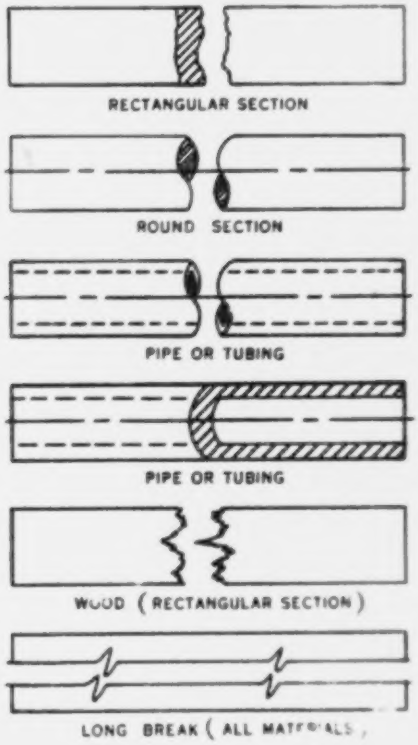

RECTANGULAR SECTION
ROUND SECTION
PIPE OR TUBING
PIPE OR TUBING
WOOD (RECTANGULAR SECTION)
LONG BREAK (ALL MATERIALS)

Figure 27 Conventional Breaks

## Scaling

Objects are drawn full size when the details of the object are clearly shown and the size of the paper will conveniently permit. Enlarged views of sections are made when the actual size of the object is so small that full-sized representations would not clearly present the features of the object. Reduced scale prints are made of large objects that can be shown clearly in a smaller scale. The prime reason for reducing the scale of drawings is to reduce their size so that they can be placed on smaller sheets without crowding the views.

The scale of prints is generally noted in the title block and can be designated as "full size", "enlarged view" or at a reduced scale such as 1" = 10', 1/4" = 1', and others which are similar.

The process of measuring dimensions on a blueprint is called scaling. Important dimensions are normally shown on the blueprint and should not be scaled because of the possible distortion of the print on cloth or paper.

## Types of Views

ORTHOGRAPHIC. The orthographic drawing normally shows three separate views, the top, front and side view (see Figure 28).

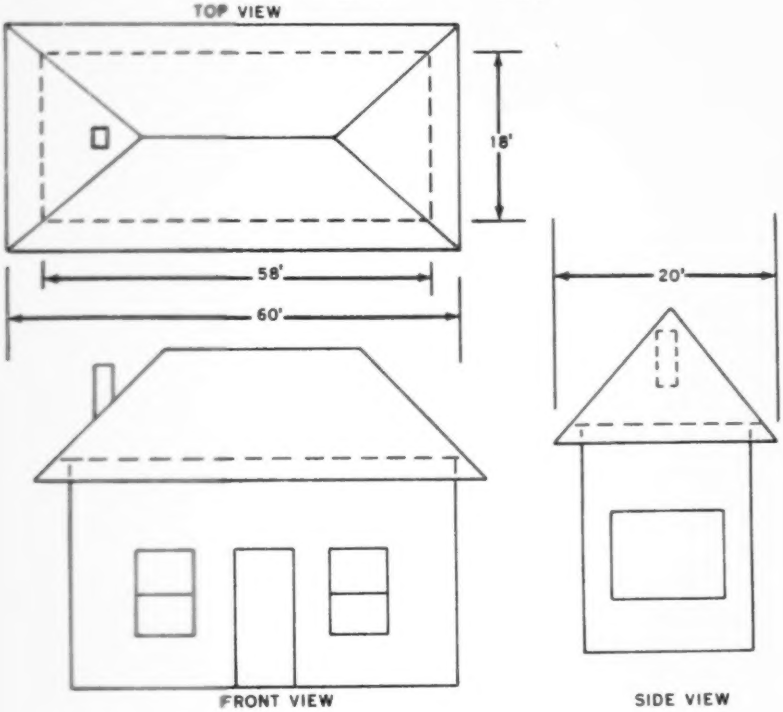


Figure 28. Orthographic Views

ISOMETRIC. The isometric drawing is a three-dimensional view (see Figure 29).

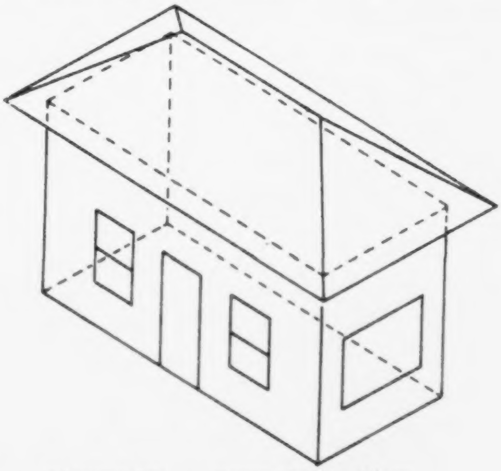


Figure 29. Isometric View

PLAN VIEWS. Plan views, or architectural blueprints, show the interior arrangement of a building. These blueprints are made looking down on a building from a point directly above. Horizontal surfaces such as floors, appear without distortion. All vertical surfaces, such as walls, appear as lines.

Plan views usually show the outside shape of a building, the arrangements of the rooms, and the size and the shapes of rooms. They often given the types of materials to be used; the thickness of walls and partitions; and the types, sizes and locations of doors and windows. They provide details of framework and structure; and they show the type, size and location of mechanical equipment, such as heating plants, radiators, plumbing, electrical fixtures and appliances. Also included are the instructions concerning the construction and the installation work.

Uses of Symbols

The symbols used in drawings are really illustrations of words or groups of words. Can you imagine a drawing without the use of symbols? Every item in construction would have to be written on the drawings by the draftsman. One can easily see why symbols are of necessity to the draftsman, and also why an efficient blueprint reader must know how to interpret them.

The symbols in the folowing charts are shown to familiarize you with some of the symbols shown on blueprints and drawings you will be using in the heating career field.

Some of the categories of blueprint symbols are: electrical, mechanical, piping, heating and plumbing. Many symbols are conventional, whereas others are not conventional. This brings us to an area of great importance, the LEGEND. This is a section of the blueprint, usually placed in the upper right corner of the drawing, or blueprint, to explain or define a symbol or a special mark that is not a conventional sign or symbol. With this additional information, the blueprint will become much more clear. Before reading a blueprint or drawing you should understand the symbols as shown in the legend.

On the following pages are Charts I through V which indicate:

______ Electrical Symbols

______ Mechanical Symbols

______ Piping Symbols

______ Heating Symbols

______ Plumbing Symbols

CHART I

ELECTRICAL SYMBOLS

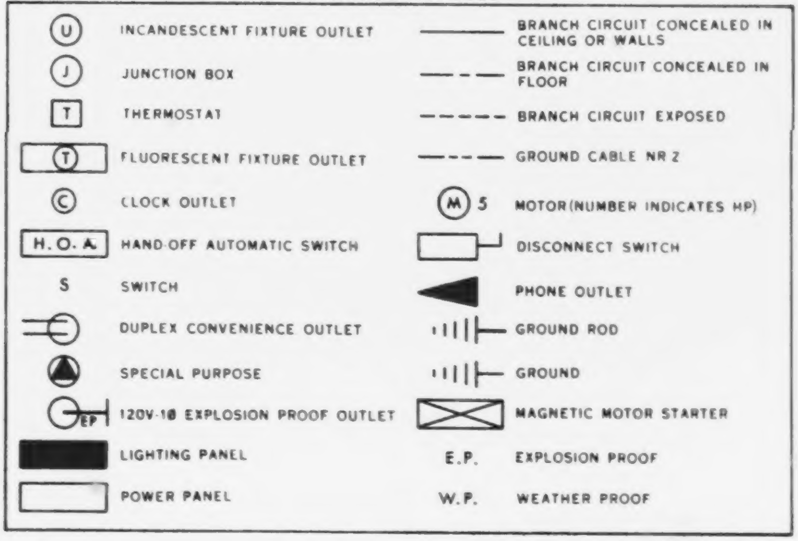
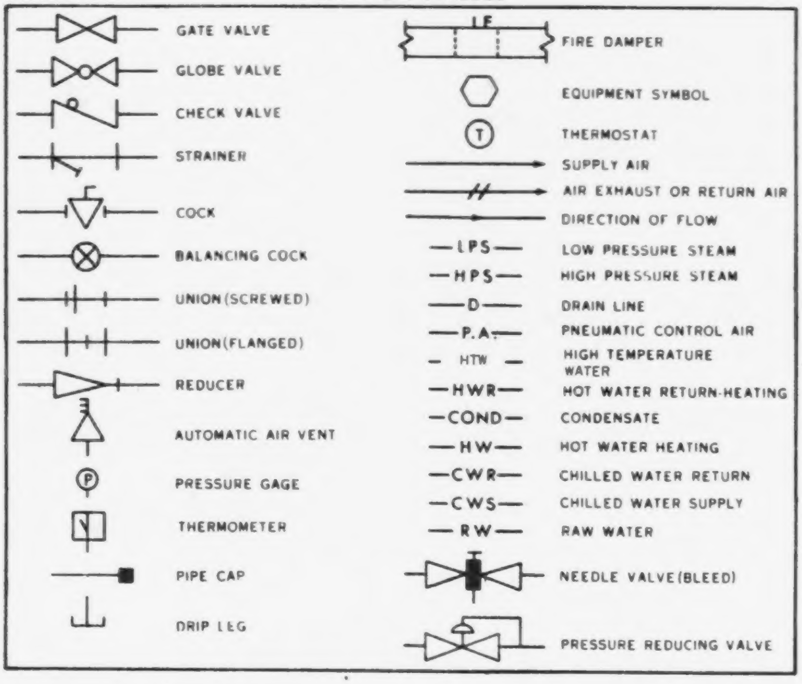

U
INCANDESCENT FIXTURE OUTLET
J
JUNCTION BOX
T
THERMOSTAT
T
FLUORESCENT FIXTURE OUTLET
C
CLOCK OUTLET
H.O.A.
HAND-OFF AUTOMATIC SWITCH
S
SWITCH
DUPLEX CONVENIENCE OUTLET
SPECIAL PURPOSE
EP
120V-1Ø EXPLOSION PROOF OUTLET
LIGHTING PANEL
POWER PANEL
BRANCH CIRCUIT CONCEALED IN CEILING OR WALLS
BRANCH CIRCUIT CONCEALED IN FLOOR
BRANCH CIRCUIT EXPOSED
GROUND CABLE NR 2
M 5
MOTOR (NUMBER INDICATES HP)
DISCONNECT SWITCH
PHONE OUTLET
GROUND ROD
GROUND
MAGNETIC MOTOR STARTER
E.P.
EXPLOSION PROOF
W.P.
WEATHER PROOF

CHART II

MECHANICAL SYMBOLS


GATE VALVE
GLOBE VALVE
CHECK VALVE
STRAINER
COCK
BALANCING COCK
UNION (SCREWED)
UNION (FLANGED)
REDUCER
AUTOMATIC AIR VENT
P
PRESSURE GAGE
THERMOMETER
PIPE CAP
DRIP LEG
FD
FIRE DAMPER
EQUIPMENT SYMBOL
T
THERMOSTAT
SUPPLY AIR
AIR EXHAUST OR RETURN AIR
DIRECTION OF FLOW
—LPS—
LOW PRESSURE STEAM
—HPS—
HIGH PRESSURE STEAM
—D—
DRAIN LINE
—P.A.—
PNEUMATIC CONTROL AIR
— HTW —
HIGH TEMPERATURE WATER
—HWR—
HOT WATER RETURN-HEATING
—COND—
CONDENSATE
—HW—
HOT WATER HEATING
—CWR—
CHILLED WATER RETURN
—CWS—
CHILLED WATER SUPPLY
—RW—
RAW WATER
NEEDLE VALVE (BLEED)
PRESSURE REDUCING VALVE

HART III PIPING SYMBOLS

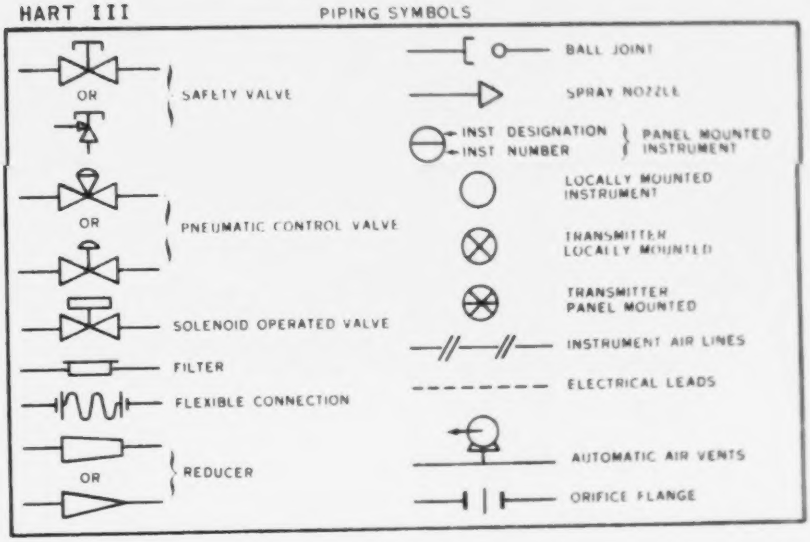

OR
SAFETY VALVE
OR
PNEUMATIC CONTROL VALVE
SOLENOID OPERATED VALVE
FILTER
FLEXIBLE CONNECTION
OR
REDUCER
BALL JOINT
SPRAY NOZZLE
INST. DESIGNATION
INST. NUMBER
PANEL MOUNTED INSTRUMENT
LOCALLY MOUNTED INSTRUMENT
TRANSMITTER LOCALLY MOUNTED
TRANSMITTER PANEL MOUNTED
INSTRUMENT AIR LINES
ELECTRICAL LEADS
AUTOMATIC AIR VENTS
ORIFICE FLANGE

CHART IV Heating Symbols

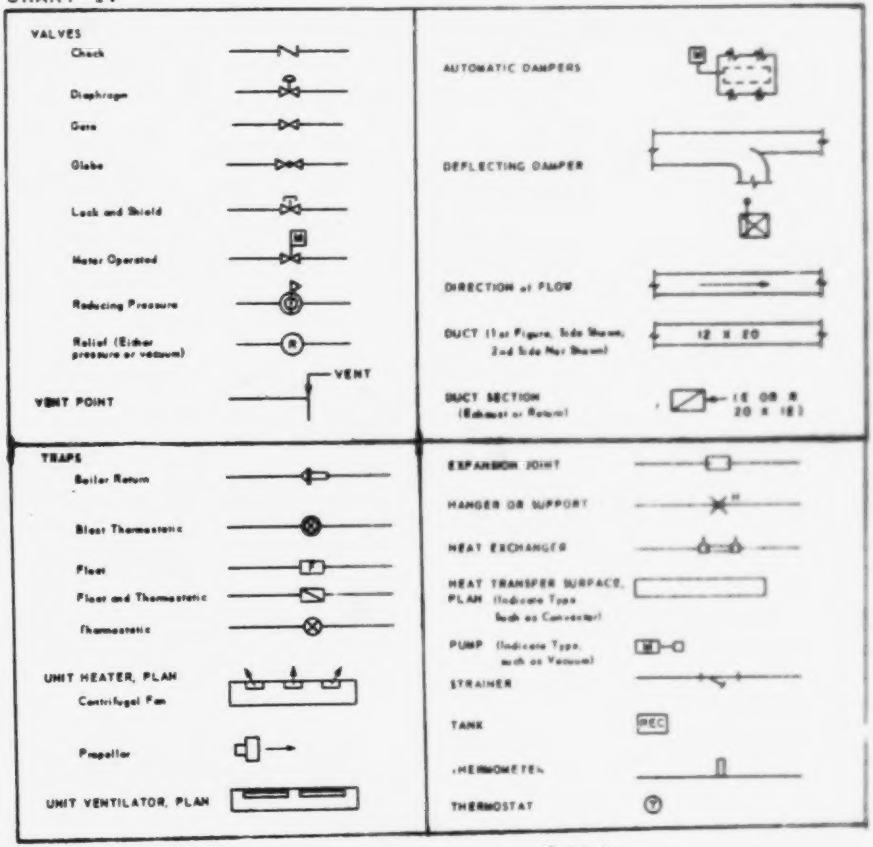
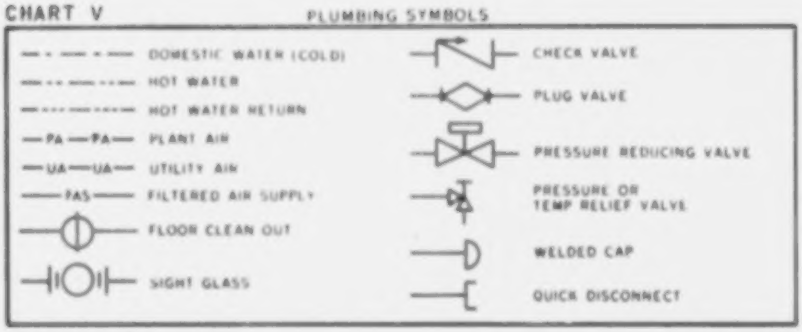

VALVES
Check
Diaphragm
Gate
Globe
Lock and Shield
Motor Operated
M
Reducing Pressure
Relief (Either pressure or vacuum)
R
VENT
VENT POINT
TRAPS
Boiler Return
Blast Thermostatic
Float
F
Float and Thermostatic
Thermostatic
UNIT HEATER, PLAN
Centrifugal Fan
Propeller
UNIT VENTILATOR, PLAN
AUTOMATIC DAMPERS
M
DEFLECTING DAMPER
DIRECTION of FLOW
DUCT (1st Figure, Side Shown, 2nd Side Not Shown)
12 X 20
DUCT SECTION (Exhaust or Return)
(E OR R 20 X 12)
EXPANSION JOINT
HANGER OR SUPPORT
H
HEAT EXCHANGER
HEAT TRANSFER SURFACE, PLAN (Indicate Type Such as Convector)
PUMP (Indicate Type, such as Vacuum)
M
STRAINER
TANK
REC
THERMOMETER
THERMOSTAT
T

CHART V PLUMBING SYMBOLS


DOMESTIC WATER (COLD)
HOT WATER
HOT WATER RETURN
—PA—PA—
PLANT AIR
—UA—UA—
UTILITY AIR
—FAS—
FILTERED AIR SUPPLY
FLOOR CLEAN OUT
SIGHT GLASS
CHECK VALVE
PLUG VALVE
PRESSURE REDUCING VALVE
PRESSURE OR TEMP RELIEF VALVE
WELDED CAP
QUICK DISCONNECT

SUMMARY

This study guide covers only a minimum amount of material concerning blueprints and symbols, the handling and care of blueprints, and their storage.

The different types of lines have been explained to give a clear-cut picture of an object or item included in a blueprint. The legend will include all necessary information needed to further explain details and symbols, and in many cases, the materials. A specific detail will be noted or referred to in the drawing.

A further study of existing blueprints, sketches and diagrams, in and around your shop area will help you in understanding other blueprints from shps, such as elctrical, sheet metal and plumbing, other than the heating plant and systems.

QUESTIONS

1. What is an object line? ______________________________

2. How are blueprints made? ______________________________

3. When is a centerline used? ______________________________

4. What is the purpose of hidden lines? ______________________________

5. What is the purpose of measuring dimensions on a blueprint? ______________________________

6. Why is a legend used? ______________________________

7. What are the electrical and mechanical symbols for a thermostat? ______________________________

8. Explain the letters, HTW, HWR, RW, HPS AND LPS. ______________________________

9. What type of heating symbol designates a gate valve, globe valve and check valve? ______________________________

10. What is another name for plan view drawings? ______________________________

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

J3ABR54532 001-I-5

# PRINCIPLES OF HEATING

## OBJECTIVE

This unit of instruction is designed to help you identify the principles of heating. By thorough study you will learn the theory of heat transfer and measurements; relationship between pressure, temperature and volume; law of gases; and metric conversion.

## INTRODUCTION

It is not known just exactly when man discovered fire, but there is no doubt that fire is one of the greatest gifts to mankind. The need to control and apply fire was clear from the very first. Imagine what living conditions were during the cave-dwelling period. Unless a natural flue or some other method of ventilation existed as a result of the cave, the smoke from fires during cold weather must have caused almost unbearable conditions, leaving the inhabitants the choice of either freezing or being asphyxiated.

Long after man had advanced to the stage of house building, heating methods had not improved to a very great degree. For centuries (and at times even today) fires for heating and lighting were contained in braziers or held to an unused corner of a room. The smoke was supposed to escape through a hole left in the roof of the building during construction. Of course, large amounts of rain and snow entered the room during bad weather. During the twelfth century, however, the people in the northern part of Europe started using crude fireplaces and flues to replace the brazier and hole-in-the roof method of heating. Some of the rudimentary heating systems still exist in France.

In the thirteenth and fourteenth centuries the round hollow stone chimneys began to be used. At the end of the fifteenth century, people were using a number of fireplaces in their homes and grouping the chimneys together in a vertical, rectangular mass of masonry with decorative effect. By the end of the Italian renaissance period, chimneys were in common use.

During colonial days in America, the fireplace chimneys were a large masonry mass projected through the center of the roof or were an important feature of the gable end walls. This general trend is often followed in architecture today. Central heating, where fires are required five or six months of the year, makes the chimney an important feature of a heating plant. There are heating installations, however, which do not make use of the masonry chimney and have substituted an inconspicuous metal smoke pipe. Other types of heating, such as electrical heating, require no chimney.

Before discussing methods of heating, it seems logical to discuss the theory of heat and the measurement and transfer of heat.

## INFORMATION

### Basic Structure of Matter

#### MATTER

By definition, matter is anything that occupies space and has weight that constitutes the observable universe, and that together with energy forms the basis of objective phenomena. Matter exists in three states: solids, liquids, and gases and the characteristics of a specific matter will tell you its state.

#### ELEMENT

An element is any one of more than 110 fundamental substances that consist of atoms of only one kind which constitutes all matter.

#### COMPOUND

A compound is any two or more of the basic element which constitutes all matter.

### MOLECULE

A molecule is the smallest partical of a substances that retains the properties of the substances and is composed of more than one atom.

### ATOM

The atom is the smallest particle of an element that can exist and is the source of vast potential energy.

## Theory of Heat Transfer and Measurement

### Heat Production

METHODS OF HEAT PRODUCTION. Heat is a form of energy that can be produced or generated by the combustion of fuels, by friction, by chemical action, and by the resistance offered to the flow of electricity in a circuit.

LAWS OF THERMODYNAMICS. Thermodynamics is the science which deals with the relationships between heat and mechanical action.

The transfer of heat is a problem to consider after the heat has been produced by the burning of a fuel. It must be moved to the space where it is to be used.

1. Heat always flows from a warmer to a cooler substance - consequently, there must be a temperature difference before heat will flow.

2. Naturally, the greater the difference in temperature, the faster the heat will flow.

3. Two objects that have different temperatures, when placed together, will tend to equalize their temperatures. As temperature increases, volume also increases.

METHODS OF HEAT TRANSFER. Heat travels in heating systems from one place to another by three different methods. All three of these methods are used in most heating systems; they are discussed in the paragraphs that follow.

Conduction. Conduction is the flow of heat from one part of a substance to another part of the same substance, or from one substance to another when they are in direct contact.

When one end of a stove poker is held in a flame, the other end will soon be too hot to hold. This indicates that the heat is being conducted or transferred from one end of the poker to the other end. Such a transfer of heat is called conduction. Conduction is used to transfer heat through the walls of a stove, furnace or radiator so that the warmth can be used for heating. If a piece of wood has been used, as an example, instead of the poker, the end of the wood away from the fire would have remained cool. This shows that some materials do not conduct as well as others. Those materials which offer considerable resistance to the flow of heat are referred to as insulators, or poor conductors.

Convection. Convection is the transfer of heat by means of mediums such as water, air and steam. When air is heated, it expands, becomes lighter in weight and rises. The cooler air, which heavier, then flows in to replace the warm air. Thus, a convection current is set up. Water, when heated, acts in the same way as air. The water next to the heating surface becomes warmer, lighter and rises. This action allows the cooler water to flow in next to the heating surface and become heated. Convection is a very important factor to be considered in a heating system. It is this force, developed by heating the medium, that circulates the heating medium to the space to be heated.

Radiation. Radiation is the transfer of heat through space. When a hand is held in front of a stove, it is quickly warmed by means of radiation. In this same manner, the earth receives its heat from the sun.

Radiated heat is transferred by heat waves, similar to radio waves. Heat waves do not warm the air through which they pass, but they must be absorbed by some substance to produce heat. For example, when you stand in the shade of a tree, you feel cool, because the leaves and limbs are absorbing the heat waves before they reach you.

When heat waves strike an object, some are reflected, some may pass through, and the rest are absorbed by the object. Polished metals are the best reflectors known; therefore, they are poor absorbers of heat. A poor absorber is also a good radiator. Rough metal absorbs heat more readily than a highly polished metal, and it also loses heat faster by radiation.

The color of a substance also affects its absorbing power. A black surface absorbs heat faster than a white one. That is why light-colored clothes are cooler in summer than dark-colored ones.

## Heat Measurement

INTENSITY. Temperature is the measurement of heat intensity in degrees Fahrenheit or Celsius (centigrade). Therefore, temperature measurements can be made by using a glass thermometer which is calibrated either in degrees Fahrenheit (°F) or degrees Celsius (°C). The generally accepted way of stating measurements of temperature is in degrees Fahrenheit.

We should stop and explain the terms Celsius and and Fahrenheit.

### FAHRENHEIT

Farenheit is relating or conforming to a thermometric scale on which under standard atmospheric pressure the boiling point of water is at 212° above the zero of the scale, the freezing point is at 32° above zero, and the zero point approximates the temperature produced by mixing equal quantities by weight of snow and common salt. Its inventor was Gabrial D. Fahrenheit, a German Physicist, (1686-1736).

### CENTIGRADE (CELSIUS)

Celsius is relating to, conforming to, or having a thermometric scale on which the interval between the freezing point and the boiling point of water is divided into 100 degrees with 0° representing the freezing point and 100° the boiling point. Its inventor was Anders Celsius a Swedish Astronomer, (1701 - 1744). Anders Celsius in 1742 devised the centigrade scale. In 1949, the U.S. National Bureau of Standards, in order to honor Anders Celsius, renamed the Centigrade Scale to Celsius.

## Types of Heat

### SENSIBLE HEAT

Sensible heat is indicated by the sense of feeling and it is the heat which can be measured by a thermometer. An example of sensible heat is presented by placing a small vessel of cold water over a gas flame and putting a thermometer in the water. The thermometer measures the degree of sensible heat of different bodies. Also upon placing your finger in the water several different times, you feel (or sense) the change in temperature that has taken place.

### HEAT GAIN

Heat gain is the term applied to heat gained by a space that is being cooled. Heat gain is produced by heat conduction through the walls, ceiling, floors, windows and doors. People and animals also give off heat.

### HEAT LOSS

Heat loss is the term applied to heat lost by a space that is being heated, or to the warming of cooler substances brought into the space. Heat loss is generally caused by conduction through walls, ceiling, floors, windows, doors, and air leakage.

QUANTITY (AMOUNT). To operate a heating unit efficiently, you must be familiar with the measurement of heat. The unit of measurement for a given quantity of heat is the British thermal unit, abbreviated and commonly known as BTU. One BTU is the amount of heat needed to change the temperature of 1 pound of pure water 1° Fahrenheit at sea level. If one BTU is added to 1 pound of water at 50° F, the temperature of that pound of water will be raised to 51° F.

LATENT HEAT. Latent heat is the amount of heat required to change the state of a substance without a measurable change in temperature. Latent heat is further clarified by the knowledge that all substances above absolute zero contain heat. There is heat even in ice, and its melting point is fixed at 32° F. Because of a fundamental law in nature, when ice at 32° F melts into water at 32° F, a change of state takes place. It is that the ice (solid) has turned into water (liquid). A certain amount of heat is required during this change of state. This heat is known as the latent heat of fusion. When 1 pound of ice changes to water, 144 BTUs are required, and an additional 180 BTUs are required to further raise the temperature of the water to 212° F at sea level.

To again change the state of this 1 pound of water (once ice) at 212° F to steam, another 970 BTUs are required. This additional heat is known as the latent heat of vaporization. (See Figure 58) Heat indicates the quantity of units of heat (BTU) in a substance, whereas temperature indicates the intensity of heat in degrees.

When we take away 970 BTUs from this 1 pound of steam at 212° F and change its state to water at 212° F, the change is known as latent heat of condensation. (See Figure 58)

We previously mentioned absolute zero. But what is absolute zero? Scientists have arbitrarily determined that when the temperature of a substance has been reduced to 460° below zero F (-460° F), practically all the heat has been removed from the subtance. At this point the molecules cease to have motion. This temperature is known as absolute zero, and it is about the lowest temperature obtainable. Heat is said to be present in all substances, when the temperature is above absolute zero.

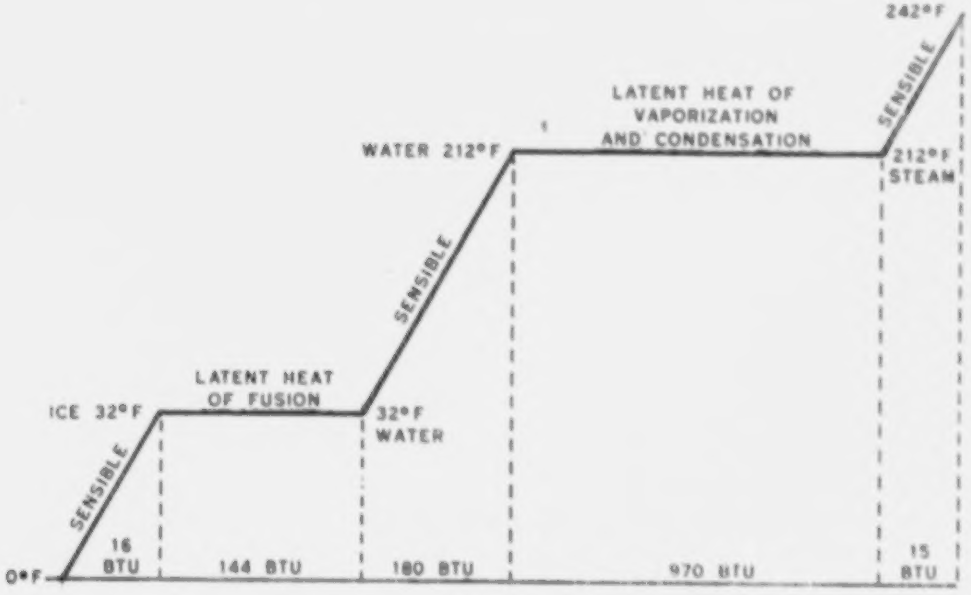


Figure 59. Sensible and Latent Heat

Problems

1. What is the number of BTUs needed to change 2 pounds of water at 212°F to steam at 212° F? (See Figure 59.)

2. Find the quantity of heat needed to change 15 pounds of water at 90° F to steam at 212° F.

STEP 1: Find the numer of pounds of water.

NOTE: When water is stated in gallons, multiply gallons by 8.3 to find its pounds. When stated in cubic feet, multiply cubic feet by 62.5.

STEP 2: Find the temperature differential. Subtract the low temperature from the high temperature.

STEP 3: If a change of state takes place add the latent heat value to the temperature differential; this is the total heat per pound.

STEP 4: To find quantity of heat required (BTUs), multiply the total heat by the number pounds of water.

NOTE: When working with heat requirements for temperatures above 212° F steam or below 32° F ice, use 1/2 BTU per pound to change the temperature one degree.

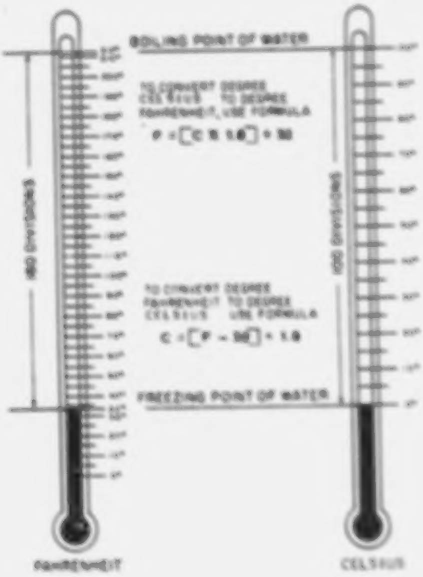

BOILING POINT OF WATER
TO CONVERT DEGREES CELSIUS TO DEGREES FAHRENHEIT, USE FORMULA
F = [C x 1.8] + 32
180 DIVISIONS
100 DIVISIONS
TO CONVERT DEGREES FAHRENHEIT TO DEGREES CELSIUS USE FORMULA
C = [F - 32] ÷ 1.8
FREEZING POINT OF WATER
FAHRENHEIT
CELSIUS

Figure 59. Comparison of Fahrenheit and Celsius Thermometers

Relationship Between Pressure, Temperature and Volume

The relationship between pressure, temperature and volume may be summarized as follows:

——— When temperature is held constant, increasing the pressure on a gas causes a proportional decrease in volume. Decreasing the pressure causes a proportional increase in volume.

——— When pressure is held constant, increasing the temperature of a gas causes a proportional incease in volume. Decreasing the temperature causes a proportional decrease in volume.

_____ When the volume is held constant, increasing the temperature of a gas causes a proportional increase in pressure. Decreasing the temperature causes a proportional decrease in pressure.

To visualize this better, the relationship can be demonstrated by an open pan, completely full of water (one quart capacity) at 60°F sea level. Raise the temperature to 200°F and the water starts to expand (volume increases) to the extent of spilling over the side. Now reduce the temperature to 60°F and the water will contract (volume decreases) to the original amount (minus the spillage). Here we have a constant pressure, plus an increase in temperature causing an increase in volume, and a constant pressure plus a decrease in temperature causing a decrease in volume.

## Law of Gases

1. Boyle's Law - "Pressure" - Reduce volume, you increase pressure and vice versa. Inverse relationship between volume and pressure.

2. Charles' Law - Charles' Law - "Temperature" reduce pressure, reduces temperature. Has a direct relationship between temperature and pressure.

3. Dalton's Law - "Partial Pressure" - Pressure of a mixture of gases will be the sum of the partial pressure of each gas in the mixture - condenser.

$$\begin{array}{r} 20 \text{ psi} \\ 20 \text{ psi} \\ \underline{10 \text{ psi}} \\ 50 \text{ psi} \end{array} \quad \text{Take Out 10 psi} = 40 \text{ psi}$$

## Metric Conversion

Temperature

FAHRENHEIT SCALE. The range of the Fahrenheit thermometer between the freezing point and the boiling point is 180° (32° to 212° = 180°).

Changing Celsius to Fahrenheit. To change degrees Celsius to degrees Fahrenheit, use either of the following formulas:

$$F° = (C° \text{ times } 1.8) + 32 \qquad \text{or} \qquad F° = (\frac{9}{5} \times C) + 32$$

Example: 50° C is what in Fahrenheit?

$$F = (50 \times 1.8) + 32 \qquad F = (\frac{9}{5} \times 50) + 32$$

$$F = 90 + 32 \qquad F = 90 + 32$$

$$F = 122° \qquad F = 122°$$

CELSIUS SCALE. On the Celsius Thermometer, the range is 100° (0° to 100° = 100°) from the freezing point to the boiling point.

Changing Fahrenheit to Celsius. To change degrees Fahrenheit to degree Celsius, use either of following formulas:

$$C = (F° - 32) \text{ divided by } 1.8 \text{ or } C = \frac{5}{9} \times (F° - 32)$$

Example:

$$C = (122-32) \div 1.8 \qquad C = \frac{5}{9} \times (122-32)$$

$$C = 90 \div 1.8 \qquad C = \frac{5}{9} \times 90$$

$$C = 50° \qquad C = 50°$$

### Length

The meter is the basic metric measurement of length. It is a little more than 3 feet 3 inches (39 inches). A smaller measurement to use is the centimeter. One inch (1") equals approximately 2.5 centimeters. Centimeter is one hundredth of a meter. For smaller measurements, you would use the millimeter. It is one-thousandth of a meter. 25 millimeters equal one inch.

### Weight

The kilogram is the basic metric measurement weight. The kilogram is equal to 1000 grams and to 2.2 pounds. The gram is one-thousandth of a kilogram and too small a measure to be convenient to work with. When measuring very small quantities by weight you would use the milligram. The milligram is one-thousandth (.001g) of a gram.

### Volume (Liquid)

The liter is the basic metric measurement for liquids. A liter is a little more than a quart. There are 3.79 liters in one gallon. A smaller measurement is the milliliter. The milliliter is one-thousandth of a liter. There are 5 milliliters to the teaspoon, 30 milliliters to the fluid ounce, and 960 milliliters to the quart. Volume measurement involves the amount of material (liquid or dry) that a space can hold. Volume is determined by multiplying length times width times depth or height. If a container is 1 foot long, 1 foot wide and 1 foot deep, it would hold 1 cubic foot. In metric system, basic volume measurement is the cubic centimeter. A cubic centimeter is space which is 1 centimeter long, 1 centimeter wide and 1 centimeter deep.

## SUMMARY

Heat is a form of energy known for its effect and is measured by intensity in Fahrenheit or Celsius (centigrade), or by quantity in BTUs. Heat is transferred by conduction, convection or radiation. Pressure has a direct effect on the boiling point of liquids.

## QUESTIONS

1. Heat may be transferred from a body to another body which is at a lower temperature by what methods?

2. On what condition is conduction dependent?

3. In what is the intensity of heat measured?

4. What is the definition of sensible heat?

5. What is the definition of a BTU?

6. What is the definition of latent heat?

7. Determine the amount of BTUs needed to change 18 pounds of water at 182° F to steam at 212° F.

8. Convert 180° F to a Celsius reading.

9. What is thermodynamics?

10. What is matter?

11. When the volume is held constant, increasing the temperature of the volume causes what to happen to the volume?

WORKBOOKS

J3ABR54532 001-I-2 thru I-5

# Technical Training

## Heating Systems Specialist

## FUNDAMENTALS AND PIPEFITTING

February 1984

3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

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This publication supersedes WBs J3ABR54532 001-I-1 thru I-5, June 1983 (Copies of superseded material may be utilized until supply is exhausted.)

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

WB J3ABR54532 001-I-2

# CIVIL ENGINEERING ORGANIZATION, SAFETY AND PUBLICATIONS

## OBJECTIVES

Given information, identify basic facts of CE mission and CE organization by correctly answering a minimum of 70% of the questions.

Given information, identify basic facts of work identification, work authorization, management and utilization of material resources by answering a minimum of 70% of the questions.

Given information, identify basic facts of AFOSH Standards and hazards of the 545X2 career field by answering a minimum of 70% of the questions.

Given information, explain individual responsibilities towards safety standards by answering a minimum of 80% of the questions.

Given information, determine safety practices when working with high intensity sound, flammables, chemicals, and acids by answering 80% of the questions.

Given information, correctly determine first aid procedures for: electrical shock, control bleeding, traumatic shock, heat exhaustion and heat stroke by answering a minimum of 80% of the questions.

Given information, identify basic facts about the two types of publication systems by correctly answering a minimum of 70% of the questions.

Given information, name the publications that pertain to the 545X2 career field by correctly answering a minimum of 70% of the questions.

## PROCEDURE

### EXERCISE 1

### Organization and Function of Base Civil Engineers

Complete the following statements, using your study guide as a reference.

1. What is the prime mission of a civil engineering organization?

______________________________________________________________

______________________________________________________________

______________________________________________________________

2. What is Air Force Regulation 85-1?

______________________________________________________________

______________________________________________________________

3. List the purpose of a work request (AF Form 332) for organizations other than civil engineering.

a. ____________________________________________________________

b. ____________________________________________________________

c. ____________________________________________________________

4. AF Form 1879 is a document used to authorize ____________________

____________________________________________________________

5. What are the branches under the operations and maintenance section?

a. ____________________ d. ____________________

b. ____________________ e. ____________________

c. ____________________ f. ____________________

6. AF Form 327, BCE Work Order, is a document used to authorize ____________

____________________________________________________________

## EXERCISE 2

### Publications

1. List the two types of Air Force publications.

a. ____________________

b. ____________________

2. What is the number and title of the technical order that will explain technical orders in the specialized publication system?

____________________________________________________________

3. What is the number of the AF publication that covers the index of standard AF publications? ____________________

4. What technical order lists numerical indexes? ____________________

5. What are Air Force regulations, manuals, and pamphlets? ____________

____________________________________________________________

6. What type information is contained in Air Force Regulations? ____________

____________________________________________________________

7. What AF manual covers the operation and maintenance of central heating plants and distribution systems?

____________________________________________________________

## EXERCISE 3

### Use Publications as Source for Inspections and Maintenance

INSTRUCTIONS

1. Using AFM 85-12, Volume I, find and identify information for performing maintenance and inspections on breechings found in AFM 85-12, Volume I, Chapter 2, Section E, paragraphs 181 and 182, to find the following information:

    a. Paragraph 181

        (1) Time intervals of inspections

        (2) Inspect for what?

            (a)

            (b)

    b. Paragraph 182

        During the boiler overhaul, what maintenance should you do on breechings?

        (1)

        (2)

        (3)

INSTRUCTION

1. Using AFM 85-12, Volume II, find and identify information for performing maintenance and inspections on warm air furnaces found in AFM 85-12, Volume II, Chapter 4, Section D, paragraphs 157 and 158 to find the following information:

    a. Paragraph 157

        (1) Time interval of inspection under subparagraph a.

        (2) Inspect for the following under subparagraph a.(1)

            (a)

            (b)

            (c)

    b. Paragraph 158

        (1) During maintenance of warm-air furnaces dealing with leaks from the combustion space, what must be done on steel furnaces to stop the leaks?

            (a)

            (b)

## EXERCISE 4

### AFOSH Standards

1. What is AFR 0-17? ______________________________

______________________________

2. Personal protective clothing and equipment are covered in which AFOSH standard?

______________________________

3. List the title of following AFOSH standards.

   a. 127-38: ______________________________
   b. 127-43: ______________________________
   c. 161-4: ______________________________
   d. 127-5: ______________________________

4. What is AFOSHSTD 127-11? ______________________________

5. What is AFOSHSTD 127-12? ______________________________

6. AFOSHSTD 161-8 covers ______________________________

______________________________

7. What AFOSH Standards cover ladders? ______________________________

8. Scaffolding is covered under what standard? ______________________________

9. List four hazards of the 545X2 specialty.

   a. ______________________________
   b. ______________________________
   c. ______________________________
   d. ______________________________

## EXERCISE 5

### Individual Responsibilities

1. Whose responsibility is it to know where to find and how to use these safety standards?

2. Who must know the purpose and use of personal protective clothing and equipment?

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

WB J3ABR54532 001-I-3

# TOOLS

## OBJECTIVES

Given information, select, use and care for the appropriate hand tools, with a maximum of two instructor assists.

Given information, select, use and care for the appropriate special tools, with a maximum of two instructor assists.

Given information, select, use and care for the appropriate precision measuring instruments, with a maximum of two instructor assists.

## PROCEDURE

## EXERCISE 1

## HAND TOOLS

1. Proceed to work area with instructors.
2. Draw necessary hand tools and material for performing objective.
3. Position necessary hand tools and material on benches in work area as directed by the instructor.
4. Each student will select the hand tools needed to remove and replace a copper connection, a screw, and a pipefitting.

CAUTION: OBSERVE APPLICABLE SAFETY PRECAUTIONS WHEN WORKING WITH HAND TOOLS. REMOVE WATCHES AND RINGS.

PROCEDURES FOR REMOVING AND REPLACING A COPPER CONNECTION.

1. Select appropriate size open end and line wrench.
2. Place open end wrench on copper union and apply stationary pressure in clockwise direction.
3. Place line wrench over copper tubing and draw up on flare nut. Apply pressure in counterclockwise direction until connection breaks loose.
4. After loose, removing by hand is desirable.
5. Instructor will inspect work.
6. After work is inspected the students will replace their connection.
7. Place tubing against flare connection and turn flare nut clockwise, threading nut by hand until tight.

   NOTE: Flare nut should turn easily, caution should be taken not to cross-thread the connection. This will cause damage.

8. Place open end wrench on copper union and apply stationary pressure in counterclockwise direction.
9. Place line wrench over copper tubing and draw up on flare nut. Apply pressure in clockwise direction until connection is tight.

   NOTE: Overtightening the connection will cause damage.

10. Clean and replace tools when task is done.

Instructor ______________________________

PROCEDURES FOR REMOVING AND REPLACING A SCREW

1. Select appropriate type and size screwdriver as directed by instructor.

   NOTE: Blade or tapered end must fill the slot or cross-slot respectively.

2. Place screwdriver correctly, and turn counterclockwise until out.
3. Instructor will check work, then replace the screw.
4. Hold screw with fingers, place screwdriver correctly, and turn clockwise until tight.
5. Clean and replace tools when task is done.

Instructor ____________________

PROCEDURES FOR REMOVING AND REPLACING A PIPEFITTING

1. Select appropriate size pipe and monkey wrenches as directed by instructor.
2. Place wrenches on pipe or fitting as directed below:
   a. Square or hexagon fitting require the use of monkey wrenches.
   b. Smooth round fittings require pipe wrenches.
3. To remove a standard pipe or fitting counterclockwise rotation is required.
4. To prevent the removal of pipe or fitting next to the pipe or fitting you are removing, a back-up wrench is required with stationary pressure in the clockwise direction.
5. For better leverage, place wrenches close together.
6. Once loose, removing by hand is desired.
7. Instructor will check work.
8. Starting by hand is needed to prevent cross-threading.
9. Turn clockwise by hand until snug, use wrench until tight.

   NOTE: OVERTIGHTENING WILL CAUSE DAMAGE TO PIPE OR FITTING OR THREADS.

10. To prevent over tightening use another wrench to apply stationary pressure in the counterclockwise direction.
11. Clean and replace tools when task is done.

Instructor ____________________

## EXERCISE 2

### Special Tools

1. Proceed to work area with instructor.
2. Draw necessary special tools and material for performing objective.
3. Position necessary special tools and material on benches in work area as directed by the instructor.

4. Each student will select the special tools needed to complete the following tasks assigned by the instructor.

PROCEDURES FOR USE AND CARE OF THE WIRING TOOL.

1. Select the size of wire as directed by the instructor.
2. Select the size on the tool to match the wire size.
3. Place wire in tool, extend the end of the wire out through the handle.
4. Squeeze handle, rotate 360°, and pull insulation off.
5. Clean and replace tool when task is done.

Instructor __________________________

PROCEDURES FOR SELECTING AND USING THE FUSE PULLER.

1. Select fuse puller for safety.
2. Select fuse puller for different size fuses.
3. Place one hand behind you. Use other hand and fuse puller to pick fuse up off table.
4. Clean and replace fuse puller when task is done.

Instructor __________________________

PROCEDURES FOR SELECTING AND USING THE PIPE VISES.

1. Select the pipe vise.
2. Place pipe in vise.
3. Center pipe in "V" grove.
4. Turn tee handle clockwise to tighten.
5. Turn tee counterclockwise to loosen.
6. Clean vise and bench when task is done.

Instructor __________________________

PROCEDURES FOR SELECTING AND USING BENCH GRINDER.

1. Select the bench grinder.
2. Select safety equipment to be used when operating the bench grinder.
3. Turn on bench grinder.
4. Turn off bench grinder.
5. Secure and clean bench grinder.

Instructor __________________________

## EXERCISE 3

### Precision Measuring Instruments

1. Proceed to work area with instructor.
2. Draw necessary precision measuring instruments and material for performing objective.
3. Position necessary precision measuring instruments and material on benches in work area as directed by the instructor.
4. Each student will select the precision measuring instruments and material needed to complete the following tasks:

PROCEDURES FOR MEASURING THE INSIDE DIAMETER OF A PIPE AND THE OUTSIDE DIAMETER OF A MOTOR SHAFT.

1. Loosen caliper, insert into end of pipe, and expand until the caliper touch the inside wall of pipe. Lock into position and read measurement.
2. Loosen caliper, expand and place on outside of motor shaft. Hold calipers' legs on motor shaft and tighten set nut to hold correct measurement. Remove and read measurement.
3. Instructor will inspect work.
4. Clean and replace tools when task is done.

Instructor ____________________

PROCEDURES FOR CUTTING A GASKET.

1. Select gasket cutter and material needed to cut a gasket.
2. Position cutter on desired section of material.
3. Secure cutter.
4. Open cutter guide to desired radius.
5. Apply light pressure to start cutting operation.
6. Continue pressure until material is cut.
7. Instructor will check your work.
8. Clean and replace tools when task is done.

Instructor ____________________

PROCEDURES FOR USING A WIRE GAGE.

1. Select the wire gage and material needed to measure different sizes of wire.
2. Wire gage is used to measure only solid wire conductor.
3. Using the wiring tool, strip off the insulation from the end of the wire being measured.
4. Insert conductor into smallest opening that conductor will enter without binding occurring at the side of the gage.
5. Instructor will check work.
6. Clean and replace tools when task is done.

Instructor ____________________

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

WB J3ABR54532 001-I-4

# PIPEFITTING

## OBJECTIVES

Given information, explain basic facts about the types and sizes of pipe and fittings by correctly answering 70% of the questions.

Given information, hand tools and pipe, measure, cut and thread pipe, with a maximum of two instructor assists.

Given procedures, mechanical threader and pipe, measure, cut, and thread a pipe nipple 12 inches long, with a maximum of three instructor assists.

Given information, select, use, and care for installed shop equipment, with a maximum of two instructor assists.

Given information, hand tools, pipe nipples and fittings, perform procedures for fabricating a piping system which will maintain system pressure with no visible leakage, with a maximum of two instructor assists.

Given information, explain basic facts about types and sizes of valves by correctly answering 70% of the questions.

Given information, hand tools and valves, perform basic step-by-step procedures for doing simple maintenance on valves, with a maximum of two instructor assists.

Given information, identify facts about reinforced thermosetting resin pipe by correctly answering 70% of the quesitons.

Given special tools and instructions, measure, cut, and connect reinforced thermosetting resin pipe, with a maximum of three instructor assists.

Given information, identify basic facts about cross-connection backflow by correctly answering 70% of the questions.

Given information, identify basic facts about hazardous piping by correctly answering 80% of the questions.

Given information, blueprints, drawings and symbols, determine step-by-step procedures for interpreting blueprints and drawings, with a maximum of two instructor assists.

## PROCEDURE

### EXERCISE 1

### Pipe and Fittings

1. What is the name for a piece of pipe less than 12 inches long? ____________________

2. What is a pipe? ________________________________________________________________

3. Which pipe is not recommended for sewer lines? ______________________________

4. Which fitting picks up a branch run at 90 degree angle? _________________________

5. What are the three classes of pipe? ______________________________________,
______________________________________, and ______________________________________

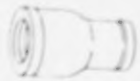
6. What fitting is used for the ease of removing and installing pipe and equipment?

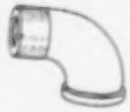
______________________________________________________________________

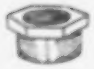
7. What fitting is used to join two straight runs of pipe? ____________________

8. What fitting makes a 90° change in direction? ____________________

9. Identify the following fittings by writing the nomenclature to the right of each fitting.

a.  ____________________

b.  ____________________

c.  ____________________

CKC-116

10. How do you measure the length of pipe? ____________________

______________________________________________________________________

## EXERCISE 2

### Piping Procedures

**CAUTION:** Observe applicable safety precautions when working with hand tools. Remove watches and rings.

1. Proceed to work area with instructor.

2. Draw necessary materials from supply.

3. Locate and position necessary tools and material on benches in work area as directed by the instructor.

4. From your instructor, obtain measurement desired; then, measure pipe and mark.

Write desired measurement in the blank space. ____________________

## PROCEDURES FOR CUTTING PIPE

1. Insert pipe in the V-shaped groove of the pipe vise and secure it.
2. Hacksaw can be used but produces a rough cut; so, whenever possible, use a pipe cutter.
3. Use a number two wheel and roller pipe cutter.
4. Position cutting wheel over mark and make a revolution with very little cutting pressure to insure proper tracking of the wheel.
5. How much should you tighten the handwheel of the cutter with each successive revolution?

   ______________________________________________

## PROCEDURES FOR REAMING PIPE

1. Use a spiral or flute reamer to remove the burr from inside the pipe.
2. Use reamer to restore inside diameter to original size. Do not overream as this will weaken the wall of the pipe.
3. Insert reamer in end of pipe and use pumping action on handle.
4. Rotate handle clockwise.
5. Use file to remove burr.

## PROCEDURES FOR THREADING PIPE

1. Assemble pipe dies.
2. Oil end of pipe before placing dies on end of pipe.
3. Push dies against pipe with heel of hand.

   NOTE: Use gloves.
4. Make three or four short clockwise strokes to start cutting operation. Use the heel of your hand to apply force to the dies.
5. Oil die segments with cutting oil to prevent overheating of the dies each time a window on the dies comes up on top.
6. Continue clockwise strokes. Every three threads reverse ratchet to clean die segments. Continue this operation until two threads extend past the dies.

7. Turn counterclockwise and remove die head.

   NOTE: Slowly turn dies counterclockwise. This prevents burrs from getting under the die segments and stripping out the threads.

8. Clean die head and put away.

9. Clean pipe threads with a wire brush.

INSTRUCTOR ____________________

## EXERCISE 3

### Mechanical Threader

CUT AND THREAD PIPE

1. Insert pipe in threader and lock front and back pipe holders into place insuring pipe is in center of the pipe holders.

2. Bring pipe cutter down from the up position insuring pipe cutter is in open position. and over pipe insuring that pipe cutter is in place on the guide.

3. Place cutting wheel on mark on pipe and turn handle on cutter clockwise until cutter is snug around the pipe.

   NOTE: Ensure that all safety precautions are followed.

4. Turn power on and start cutting pipe by turning the handle 1/4 turn for each 360 degrees rotation of pipe.

5. After pipe is cut return cutter to up right position and lower pipe reamer without stopping threader.

6. Position reamer in guide, this will place reamer directly in line with the pipe.

7. Next turn the wheel on the guide counterclockwise until the reamer enters the end of the pipe.

8. Apply a steady but light force on the wheel until the bur is removed from the end of the pipe.

   NOTE: To ream too much out of the end of the pipe will weaken the pipe wall as well as to enlarge the end of the pipe.

9. Withdraw reamer from end of the pipe and return it to its upright position without stopping threader.

10. Lower adjustable threader into guide and lock dies into position by lowering small handle on dies.

11. Ensure dies are set on correct size for the pipe to be threaded.

12. Do not start to thread pipe till the cutting oil starts to flow out of the dies.

13. Turn the wheel on the guide counterclockwise until dies rest on the end of the pipe.

14. Apply a steady but light force on the wheel until the dies start to thread themselves on the pipe, at that time release the wheel.

15. The die will thread itself onto the pipe. When the correct number of threads are made, open the lock on the dies by lifting up on the lever on the dies. The number of threads depends on the working pressure.

NOTE: Don't lift up too hard, as damage to threads is possible.

16. Withdraw dies by turning wheel clockwise until clear of the pipe.

17. Repeat the cutting operation starting with step 2 through step 4, then stop the threader.

18. Remove pipe nipple from threader and clean the threader.

19. Bring pipe nipple to instructor for grading.

INSTRUCTOR ____________________

## EXERCISE 4

### Installed Shop Equipment (Power Threader)

1. What is used to cut the pipe on the power threader?

2. What type of reamer is on the threader?

3. Which direction do you turn the wheel on the guide to have the reamer enter the pipe?

4. What must you look for before you start to thread pipe?

5. Which direction do you turn the wheel on the guide to start the dies to thread the pipe?

6. What is the time intervals between oil changes on the power threader?

7. When should the dies be changed?

8. What is used to hold turning pipe?

9. Who should make adjustments on the transmission speeds on the power threader?

INSTRUCTOR ____________________

## EXERCISE 5

### Fabricating Pipe System

1. Apply pipe joint compound. Describe how pipe joint compound is applied.

   ____________________________________________

2. Start fitting by hand, making sure not to cross-thread it.
3. Turn fitting or pipe by hand until snug.
4. Use two wrenches to tighten. This prevents the turning of other pipes or fittings.
5. Fabricate the piping system which your instructor will assign to you.
6. Upon completion of your project, your instructor will pressure-test it and grade your performance.
7. Clean all tools and equipment.
8. Replace all tools and equipment.
9. Clean up the work area.

INSTRUCTOR ____________________

## EXERCISE 6

### Types and Sizes of Valves

1. Which valve is used to regulate flow? ____________________

   ____________________________________________

2. To prevent binding, what must be done to a gate valve? ____________________

   ____________________________________________

3. How can you tell if a valve has a rising or nonrising stem? ____________________

   ____________________________________________

4. If the valve is installed in the system, how can you tell which type valve it is?

   ____________________________________________

5. What do the letters WOG stand for on valves? ____________________

   ____________________________________________

INSTRUCTOR ____________________

## EXERCISE 7

### Maintenance of Valves

1. What maintenance action is necessary if the valve body is cracked? ______________

______________________________________________

2. Describe maintenance action for small and large brass valve seats?

   a. Small valve: ______________________________

   ______________________________________________

   b. Large valve: ______________________________

   ______________________________________________

3. What is the main advantage of a composition discover a conventional disc?

______________________________________________

4. Repack a gate valve using the following procedures.

   a. Remove wheel nut using adjustable wrench.

   b. Remove wheel with hand, insuring the name tag is not lost in removing wheel.

   c. Remove packing nut with adjustable wrench by turning counterclockwise.

   d. Remove packing gland by lifting it out of stuffing box.

   e. Remove packing with the aid of the packing remover.

   NOTE: Count the number of rings of packing removed, the same number should be replaced.

   f. Measure new packing by placing packing around stem and cutting at a 45 degree angle and off setting the ends at 90 degree angles in the stuffing box.

   g. Once packing is back in the stuffing box the process is reversed.

      (1) Replace packing gland

      (2) Replace packing nut with hand till snug, then using adjustable wrench turn clockwise till tight.

   NOTE: DON'T over tighten packing nut.

      (3) Replace wheel and name tag.

      (4) Replace wheel nut with hand till snug, then using adjustable wrench turn clockwise till tight.

   NOTE: DON'T over tighten wheelnut.

INSTRUCTOR ______________

## EXERCISE 8

### Reinforced Thermosetting Resin Pipe

1. Whose arrangement for shipping and storage do we follow as our guide for the same?

___________________________________________

2. Where should the tie downs be placed? ____________________

3. What is recommended for tie downs? ____________________

4. How far can you safely extend the pipe beyond the truck or trailer bed? ________

5. What is the nominal weight of a 12 inch pipe/ft? ____________________

6. What is the angle of taper for a 4 inch pipe? ____________________

7. What affects the pot life of the adhesive? ____________________

8. What is the maximum height you can stack resin pipe? ____________________

INSTRUCTOR ________________

## EXERCISE 9

### Connecting Thermosetting Resin Pipe

1. Proceed to work area with instructor.

2. Draw necessary hand tools and material for performing objective.

3. Position necessary hand tools and material on benches in work area as directed by the instructor.

4. Each student will select all tools and materials needed to do objective.

### PROCEDURES FOR MEASURING THERMOSETTING RESIN PIPE

1. Secure pipe with the use of a strap wrench, saw guide-clamp assembly, or a chain vise.

   NOTE: Always wrap the pipe with a protective material (such as rubber) to prevent damage to outer surface.

2. Thermosetting resin pipe is measured same as pipe, by outside diameter (O.D.). The length of resin pipe is also measured the same as pipe, end to end, end to center, center to center.

3. Obtain measurement from instructor, measure and mark pipe.

## PROCEDURES FOR CUTTING AND TAPERING THERMOSETTING RESIN PIPE

1. Place saw guide or a wrap around may be used to insure a straight as possible cut; this is very important for proper tapering of the pipe ends.

2. For pipe 2" - 6" a fine-toothed hacksaw should be used, and for pipe 8" - 16" a power driven circular abrasive cutter wheel should be used.

   NOTE: Protective respirators should be worn when using powered cut-off or tapering equipment.

   NOTE: 32 teeth per inch or the rule which states 3 teeth must be in contact with the surface being cut at all times.

3. Place a facing tool in the end of the pipe and rotate tool clockwise, this will check and if needed square end of pipe.

4. Remove facing tool from pipe and replace with tapering tool.

5. Rotate tapering tool in clockwise direction. The angle of taper is built into the tapering tool.

   NOTE: Ensure that all safety precautions are followed. Read instructions carefully.

## PROCEDURES FOR JOINING THERMOSETTING RESIN PIPE

1. Thoroughly clean all surfaces with joint cleaner to remove all dirt, grease and foreign materials.

   NOTE: Do not touch the bonding surfaces.

2. Ensure all surfaces are clean prior to adhesive application.

3. To mix the adhesive, first empty all the hardener into the can of resin.

   NOTE: NEVER SPLIT A KIT

   Mix the entire contents of the two containers together with a tongue depressor (wooden), until a uniform pink color. Get all resin from lid and under lip of can.

4. Use the wood stick to apply adhesive to pipe, insuring not to touch pipe or adhesive with bare hands.

5. Align pipe lengths, apply force to lock the joint, taking care not to disturb or move the joined piping until the adhesive has cured.

6. Instructor will check work.

7. Clean and replace all tools and equipment when finished.

INSTRUCTOR ____________________

## EXERCISE 10

### Backflow/Cross Connection

1. What is a pollutant? ______________________________

2. Describe backflow. ______________________________

______________________________

3. What is a physical arrangement in which a public potable water supply is connected in direct contact with a non-potable water system?

______________________________

4. What is backpressure? ______________________________

5. What is back-siphonage? ______________________________

6. What is a contaminant? ______________________________

INSTRUCTOR ____________

## EXERCISE 11

### Identification of Hazardous Piping

1. What is Federal Standard 595? ______________________________

2. Flammable materials are marked by which color? ____________

3. Brown represents ____________ and ____________ materials.

4. Physically dangerous materials are ____________ in color.

5. Green represents ______________________________.

6. Compressed air is coded by ____________ as a secondary color.

7. What is natural gas primary color? ____________

8. Potable water (less than 50 psi) is coded by which color? ____________

INSTRUCTOR ____________

## EXERCISE 12

### Blueprints and Symbols

1. What is an object line? ________________________________________

2. What is the simplest and most generally used copying process for making prints?

________________________________________________________________

3. What is a centerline used for? ________________________________________

4. The process of measuring dimensions on a blueprint is called ____________________

5. Name the types of views used in blueprints. ____________________________

________________________________________________________________

6. What is the symbol for a thermostat?

   a. Electrical ____________________________

   b. Mechanical ____________________________

   c. Heating ____________________________

7. What is the symbol for a gate valve?

   a. Mechanical ____________________________

   b. Heating ____________________________

8. What is the symbol for a globe valve?

   a. Mechanical ____________________________

   b. Heating ____________________________

9. Which type of view is known as architectual blueprints?

________________________________________________________________

INSTRUCTOR ____________________

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

# PRINCIPLES OF HEATING

## OBJECTIVES

Given information, identify basic facts of the structure of matter and thermodynamics by correctly answering 70% of the questions.

Given information, identify basic facts of the laws of gases by correctly answering 70% of the questions.

Given information, identify basic facts of metric conversion by correctly answering 70% of the questions.

## PROCEDURE

### EXERCISE 1

### Temperature Conversions and Pressure, Temperature, and Volume Relationship

1. Of the two ways of measuring heat, the thermometer is used to measure the

______________________________________________

2. Using the appropriate formula, convert the following temperatures.

F = (C x 1.8) + 32 or C = (F - 32) ÷ 1.8

a. (212°F) ______________________________

b. (70°C) ______________________________

c. (132°C) ______________________________

3. Enter the boiling and freezing point on the following temperatures:

a. Celsius - Freezing __________°C Boiling __________°C

b. Farenheit - Freezing __________°F Boiling __________°F

4. Write the name of the kind of heat that changes the temperature but does not change the state of the substance.

______________________________________________

5. Define the term "sensible heat."

______________________________________________

______________________________________________

______________________________________________

6. What is matter? ______________________________

7. What is a molecule? ______________________________

8. What is thermodynamics? ______________________________

______________________________________________

9. Name the three methods of heat transfer

a. ______________________________________________

b. ______________________________________________

c. ______________________________________________

10. What is thermal conduction? ______________________________

______________________________________________

11. List the three types of latent heat and give BTU value for each.

a. ______________________________________________

b. ______________________________________________

c. ______________________________________________

12. What kind of heat is required to convert water to steam?

______________________________________________

13. Determine the quantity of heat needed to change 15 gallons of water at 90°F to steam at 212°F.

STEP 1: Find the number of pounds of water by multiplying gallons by 8.3.

STEP 2: Subtract low temperature from high temperature to get temperature differential and convert to BTUs.

STEP 3: If a change of state takes place, add the latent heat value in BTUs to the temperature differential in BTUs; this is the total heat for one pound.

STEP 4: To find quantity of heat (BTUs) required, multiply the total heat by the number of pounds of water.

NOTE: When working with heat requirements for temperature above 212°F steam or below 32°F ice, use 1/2 BTU per pound to change the temperature one degree.

14. Determine the number of BTUs required to change 15 pounds of ice at 10°F to steam at 242°F.

______________________________________________

15. Determine how many BTUs are required for latent heat of fusion.

______________________________________________

16. When the temperature of water increases, what happens to its volume?

______________________________________________

17. What happens to pressure if the volume of water in a closed container increases?

____________________________________________

18. What happens to the boiling point of water when the pressure increases?

____________________________________________

## EXERCISE 2

1. What is the temperature scale for the metric system?

2. Using the appropriate formula, convert the following temperatures.

Degree of farenheit = (9/5 x degree of celsius) +32+
Degree of celsius = 5/9 x (degree farenheit -32)

a. (100 degree celsius)

b. (94 degree farenheit)

c. (126 degree celsius)

3. What is the basic metric measurement of length?

4. Using the formula for length, convert the following lengths.

1km = 100 m., 1m = 39.37 inches or 3.28 feet

a. 4 meters ____________________ inches

b. 15 feet ____________________ meters

c. 3280.8 feet ____________________ km

5. What is the basic metric measurement for weight?

6. Using the formula for weight, convert the following weights.

1 gram (g) = 15.4 grains (gr), 7000 (gr) = .4536 (kg) or 11b

1 kilogram = 1000g = 2.21b, 1 lb = 453.6 g

a. 5000(g) = ____________________ lb

b. 1000(g) = ____________________ gr

c. 500(kg) = ____________________ lb

7. What is the basic metric measurement for volume (liquid)?

8. Using the formula for volume convert the following volumes.

1000 mili = 1 litre, 3.784 L = 1 gal, 946 mili = 1 qt, 473 mili = 1 pt

a. 4 qt = ______________ milliliters

b. 12 liters = ___________ gal

c. 3784 mililiters = ___________ pt

J3ABR54532 001-II-1 thru II-6

# Technical Training

# Heating Systems Specialist

# BASIC ELECTRICITY

October 1984

3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

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3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

# ELECTRICAL FUNDAMENTALS

## OBJECTIVES:

Given information identify basic facts relating to electrical fundamentals by correctly answering 70% of the questions.

Given fuses, fuse puller and fused safety switch, install circuit protective devices with a maximum of two instructor assists.

## INTRODUCTION:

This unit is designed to familiarize you with electrical safety practices. It will also provide you with information to help you understand electrical fundamentals and will give you instructions relating to the "hands on" installation of circuit protective devices.

The material in Unit 1 is presented under the following main topics:

- ELECTRICAL SAFETY AND FIRST AID
- ELECTRICAL THEORY
- VOLTAGE
- CURRENT
- RESISTANCE
- ELECTRICAL WIRING PRACTICES
- CONTROLLING ELECTRICITY
- COMMON ELECTRICAL SYMBOLS

## INFORMATION:

### ELECTRICAL SAFETY AND FIRST AID

Safety is the responsibility of every individual. This includes personal safety and the safety of others. However, human nature is such that no one individual can ever be 100% alert 100% of the time to every accident producing possibility. This is why each person must be as fully aware as possible of the causes of accidents and the hazards of each particular job. Future heating technicians should also be familiar with basic first aid procedures for electrical shock victims and the control of fires which may occur in and around heating equipment.

Common sense is probably the one best "rule of thumb" to follow in order to stay safe, both on and off the job. By definition, common sense is "normal intelligence." Take time to THINK!!!

Most accidents are caused by the unsafe act of an individual. Equipment failure accounts for only a small percentage. The following is a list of the common causes of accidents. Note the human element of carelessness:

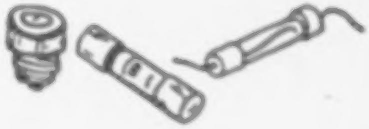
- Operating equipment without proper training, experience, or authority.
- Not following safety precautions and instructions.
- Not using safety guards or devices provided.
- Working at unsafe speeds or in an unsafe body position.
- Careless housekeeping.
- Operating with tools or equipment known to be unsafe.
- Indulging in horseplay.
- Failing to warn others of possible dangers.
- Fatigue.

Many of the hazards to be confronted as a heating specialist will be associated with careless maintenance practices. Do not omit safety precautions no matter how insignificant they may seem.

The risks of electrical shock can be avoided by the use of common sense, knowledge, and safety precautions. High voltages will cause severe shock and large sums of current will cause damaging burns.

It is important that we all know and understand the safety procedures for each type of equipment. High voltage systems are turned OFF when work is being performed on them. Turning on the equipment at these times could be disastrous.

All types of electrical equipment will have a fuse or some other circuit protective device. A fuse is a sensitive device which will shut off the power to a unit when something goes wrong. This will stop further damage to the unit. A "blown" fuse is not a defect. The trouble which causes the fuse to blow must be located and corrected. Never replace a blown fuse with anything but a fuse of the correct type and rating.



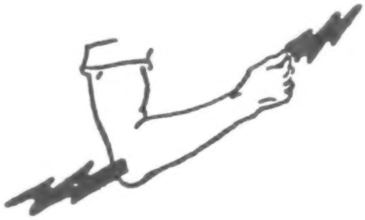
Unfortunately, a fuse that is designed to protect the equipment will not protect the operator. A very small amount of current passing through the chest can cause death, yet this same amount of current might NOT blow the fuse. The point is, a fuse was never meant to protect human life.

The amount of electricity required to electrocute a person depends upon several factors:

- The amount of electrical current
- The area of the body involved
- The length of time the shock is received
- The health of the person

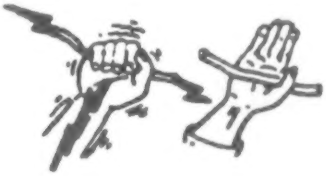
Even people in excellent health may be severely affected by electrical shocks which are minor. They sometimes respond by passing into a depressed condition of body functions called Traumatic Shock. Traumatic Shock, if allowed to continue, may cause death.

Suppose, for example a shock is received from a finger to the elbow. The electrical current will pass thru the forearm. Puncture wounds and burns may be received on the fingers and the elbow where the electricity enters and leaves. Also, internal burns within the arm can cause tissue and nerve damage. The higher the current, the greater the damage.



A shock of this type does not usually last too long. The muscles of the arm will contract and break the current path. Contraction of the arm muscles can cause injury with tools held in the hand. Any tool can become a deadly weapon as a result of even a minor shock. Fractures of the arm may also occur if it strikes a solid object during contraction.

Contracting of the fingers can lock the hand to the wire, creating a very serious situation. This condition must be avoided.



The most dangerous shocks are those that involve the brain or vital organs in the chest and abdominal areas.

Severe electrical shocks usually involve paralysis. The brain's messages can be disrupted and breathing or heart action becomes disorganized or stopped. Sometimes the heart is still operating but instead of a rhythmic beat, the heart flutters with a series of uncoordinated, rapid, weak pulsations. (Ventricular Fibrillation). This is fatal if it continues for any length of time.

Paralysis due to electrical shock usually causes the victim to stop breathing. Artificial respiration must be started as soon as the victim is free of the electrical source. Remember--the victim is usually unable to help himself.

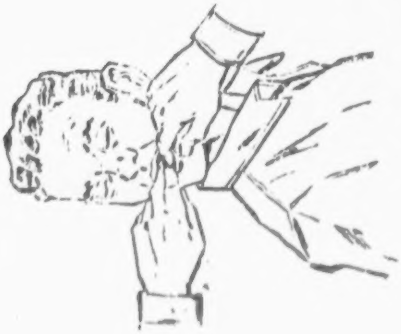
TURN OFF THE POWER as quickly as possible. If unable to locate the power switches; WARN OTHERS of the immediate danger and proceed to remove the victim from the power source, using a dry wooden pole, wooden broom, or dry wooden chair to push or roll the victim clear of the power source.

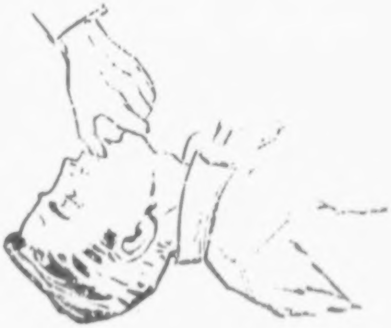
Artificial Respiration:

The most important thing to remember in giving artificial respiration is to BEGIN IMMEDIATELY. Once the victim is free of the power source, don't waste time moving to an "ideal" location, or waiting for some other qualified assistance. BEGIN IMMEDIATELY!!!

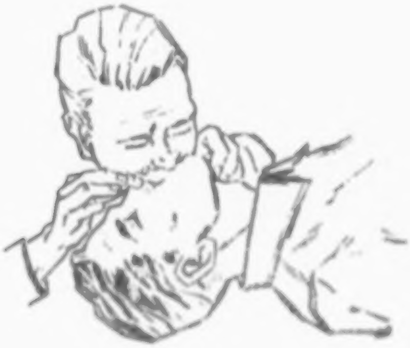
Place the victim on their back. Use your fingers to clear the mouth and throat.

PULL the lower jaw forcefully outward so that the lower teeth are further forward than the upper teeth. Keep the victim's head back as far as possible in a "sword swallowing position."





Close the victim's nose. Blow air into the lungs until the chest rises. Repeat 12 to 20 times per minute.



If the chest does not rise when you blow, improve the position of the victim's air passageway, and blow more forcefully. Blow forcefully into adults, and gently into children. After the chest rises, quickly separate contact with the victim's mouth and let the air out of their lungs. Continue rhythmically without interruption until the victim starts breathing.

## Closed Chest Cardiac Massage

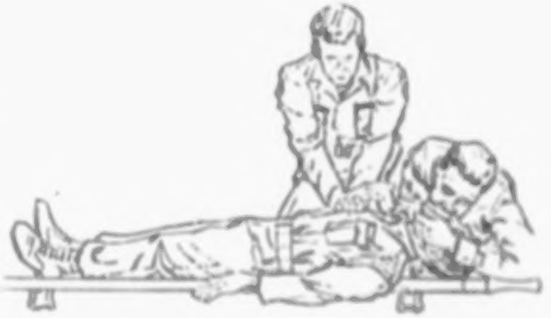
It is imperative that blood circulation be maintained while the mouth-to-mouth respiration is being performed. A quick method of determining if the heart has stopped beating is to lift the victim's eyelid and observe the pupil. If the pupil is dilated (enlarged), the heart has stopped beating and artificial blood circulation must be maintained through the revival procedure, or until natural heartbeat is reestablished.

Follow the procedure listed below to establish and maintain circulation.

1. Lay the patient face up on a solid support, such as the floor, ground, or pavement. A bed or couch is too soft.

2. Clear the patient's throat and mouth of any foreign matter.

3. Begin mouth-to-mouth resuscitation simultaneously with heart massage. If two people are available, one gives mouth-to-mouth resuscitation while the other gives closed chest cardiac massage. If only one person is available, alternate eight counts of cardiac massage with two counts of mouth-to-mouth breathing.



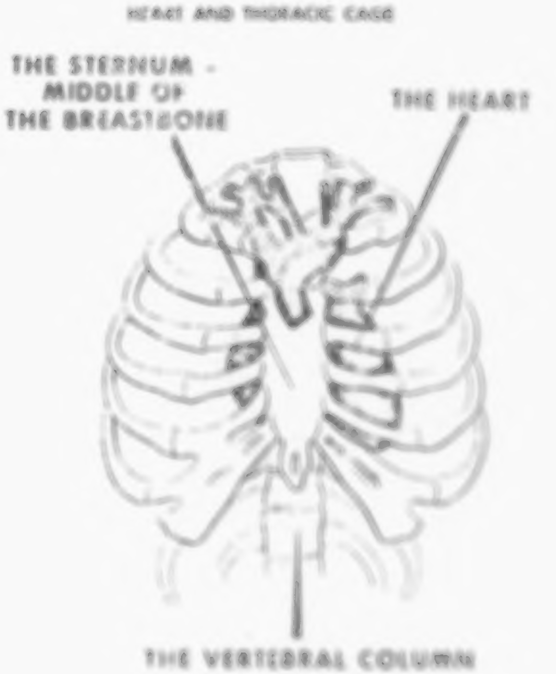
Two Person Heart/Lung Resuscitation Method

4. Kneel at right angles to the patient's trunk so you can use your weight in applying pressure.

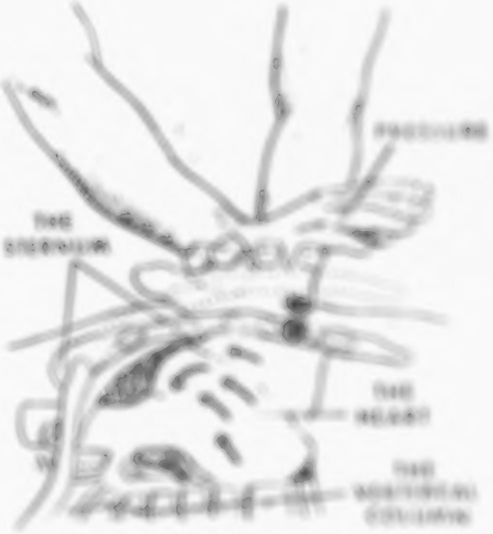
5. Place the heel of your right hand on the breastbone of the patient, with fingers spread and raised so that pressure is only on the breastbone, but not on the ribs. Place your left hand on top of the right, and press vertically downward--apply enough pressure to depress the breastbone from one and one-half to two inches. The chest of an adult, although resistant when he is conscious, becomes surprisingly flexible when he is unconscious.

   NOTE: With a child, use only one hand and relatively light pressure. In newborn infants, use of fingers only may be sufficient.

   NOTE: The heart is located between the sternum (breastbone) and the vertebral column. Pressure on the breastbone forces the heart against the spine, thus forcing blood into the arteries. Release of pressure allows the heart to refill with venous blood.


HEART AND THORACIC CAGE
THE STERNUM - MIDDLE OF THE BREASTBONE
THE HEART
THE VERTEBRAL COLUMN

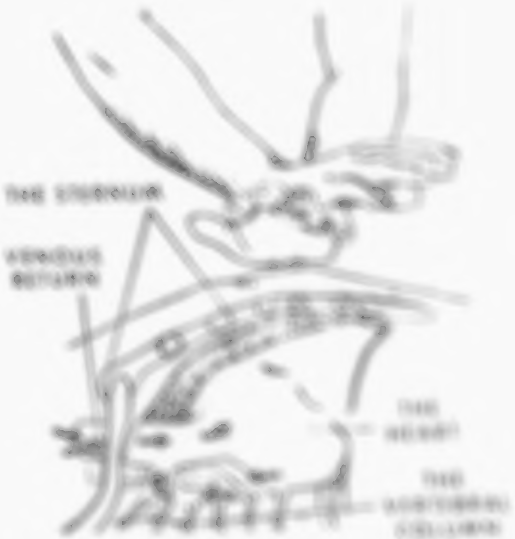
Heart and Thoracic Cage


PRESSURE
THE STERNUM
THE HEART
THE VERTEBRAL COLUMN

Pressure Pushes Blood Out of Heart

6. Release the pressure immediately, lifting the hands slightly, then repeat in a cadence OF APPROXIMATELY 60 THRUSTS PER MINUTE.

7. Continue closed chest cardiac massage until you get professional medical aid. Also, if possible, continue to give mouth-to-mouth resuscitation until someone arrives with a tank of oxygen to take over. If you are on your own and the victim shows no response, continue both measures until the victim becomes stiff (rigor mortis sets in). Even trained and experienced medical personnel find it increasingly difficult to say when a person is really dead beyond recall. Again, the most important point is to immediately begin and continue resuscitation efforts.


THE STERNUM
VENOUS RETURN
THE HEART
THE VERTEBRAL COLUMN

Electrical Safety Practices:

As a heating specialist, you may be required to perform minor electrical repairs. Electrical safety practices must be followed to minimize the possibility of accidents. It would be impossible to list every safety precaution in this study guide, but an attempt has been made to provide you with a partial listing of common electrical safety practices. Additional information on electrical safe practices can be found in Air Force Pamphlet 85-1, Electrical Facilities Safe Practices Handbook.

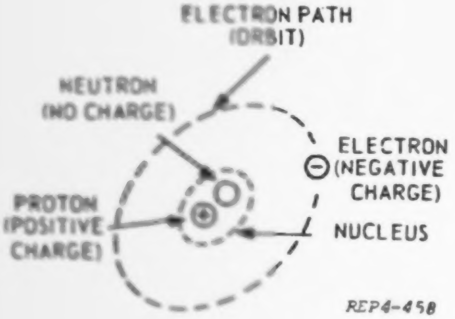
1. All repair and maintenance work on electrical equipment must be performed by qualified, authorized personnel.
2. Before beginning any electrical work, remove all rings, wrist watches, bracelets and other metal items that might accidentally come in contact with a live wire.
3. Become familiar with equipment you will be expected to maintain.
4. Learn the location and proper use of fire extinguishers.
5. Whenever possible, electrical circuits and equipment will be de-energized before working on them.
6. Don't work alone when working with electricity.
7. Don't take anything for granted; treat all wires and terminals as though they were energized (unless proven otherwise).
8. Perform pre-operational inspections before operating electrical equipment.
9. Report safety hazards to your supervisor, warn others and use appropriate warning tags to identify unsafe or hazardous conditions.
10. Insure adequate illumination and ventilation while performing any job related task.
11. Avoid horseplay (unnecessary distractions, startling workers, etc.)
12. Avoid using aluminum ladders near live electrical wires.
13. Stay dry...water increases electrical dangers.
14. Practice good housekeeping.
15. Pay attention to all warning tags and signs.
16. Inspect all tools for proper operation and safety.
17. Never bypass an electrical protective device.
18. Fuse types and sizes must not be changed without engineering assistance.
19. Use common sense and THINK!!!

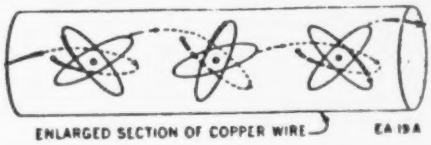
# ELECTRICAL THEORY

Electricity is something to be respected. This is due to the fact that it can not be seen and also because of the possibility of injury or death if proper care is not used when working with it. As you become familiar with this form of energy you should learn to respect it. Due to its proper handling and use, electricity has become one of the greatest helps known to man. To properly handle and use it, you will first have to understand some of the rules for this form of energy.

Many things in existence can be grouped under the general classifications of matter or energy. Matter can be defined as anything that occupies space and has weight. Energy can not be seen but can have an effect on matter. Energy can be defined as the ability to do work. It can take various forms such as mechanical, chemical, heat and electrical energy. Any of these forms of energy can be changed from one form to another.

Scientists have broken down matter into more than 100 different substances called elements. An element such as copper, gold or carbon is a substance that cannot be broken down to a more simple substance by ordinary means. All matter is made up of elements or combinations of elements. The smallest part of an element is the atom. Atoms are so small that several billion of them could fit on the head of a pin. Each atom is made up of protons, neutrons and electrons. Protons have a positive electrical charge, neutrons are neutral and have no charge, while electrons have a negative charge.

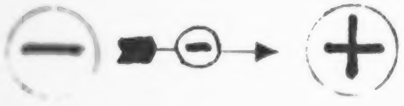




Electron movement in a conductor

An atom in its normal condition has an equal number of electrons and protons and shows no sign of electricity. If through some force, an atom loses or gains an electron, it becomes unbalanced or electrically charged. Atoms that have gained electrons are negatively charged while atoms that have lost electrons are positively charged. Unbalanced atoms of different charges will attempt to become balanced again.

The ELECTRON THEORY explains that charged atoms can regain balance because of the movement or flow of electrons from a negative electrical charge to a positive electrical charge.



## VOLTAGE

Voltage is the electrical energy, force or pressure that can cause electron flow. Voltage can be represented by the differences in negative and positive electrical "potentials" or charges. Differences in electrical charges (- +) are measured in volts with a voltmeter. There are many common devices that can be used to produce voltage. Each device has the ability to convert some form of energy into electrical energy.

A battery is an example of a device that converts chemical energy into electrical energy. Chemical reactions take place inside of the battery and cause migration of electrons from one terminal to another. The terminal that gains electrons is considered to be negative while the terminal that loses electrons is considered to be positive. A battery will remain charged as long as there is chemical action taking place to produce voltage.

A thermocouple is an example of a device that converts heat energy into electrical energy. Two dissimilar metal wires are welded together at the ends to form a thermocouple. When heat is applied to the thermocouple, electrons migrate from one metal to another, producing negative and positive electrical charges. A thermocouple will produce voltage as long as the two dissimilar metals are heated.

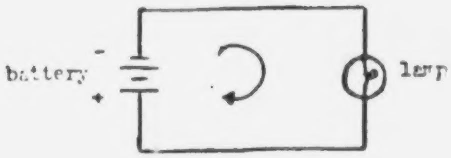
A mechanical generator is an example of a device that converts mechanical energy into electrical energy. A mechanical generator causes a magnetic field to pass through a conductor. As the magnetic field passes through the conductor it produces negative and positive electrical charges.

## CURRENT

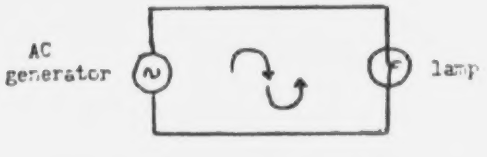
Current is a term used in electricity to describe the rate of electron flow from a negative to a positive electrical charge. A circuit is a complete path for current flow. The amount of current flow through an electrical circuit is measured in amperes with an ammeter. One ampere (sometimes called an amp) of current represents the movement of more than six (6) quadrillion electrons!

Electrical current can produce many interesting and useful effects. In fact, current flow is responsible for the operation of all electrical devices. Some examples of the useful effects of current include the ability to produce chemical reactions for the chrome plating of bumpers, heat from irons to iron our uniforms, and magnetism to operate fan motors to help keep us comfortable. Unfortunately the misuse of electrical current can cause electrical shock, electrical burns or DEATH.

There are two types of electrical current: direct current (DC) and alternating current (AC). Direct current represents electron flow through a circuit in one direction only; from the negative side of the power source, through the circuit to the positive side of the power source. This is the type of current produced by a battery. Alternating current represents electron flow in alternating directions. (Current flow is still negative to positive.) Alternating current begins its cycle in one direction but then as though someone gives out the command "TO THE REAR...MARCH," the electrons begin to flow in the opposite direction. A complete cycle is called a Hertz (Hz). American power companies provide alternating current at 60 Hz while European power companies generally provide 50 Hz. This type of current is provided by alternating current generators.



DIRECT CURRENT



ALTERNATING CURRENT

## RESISTANCE

Resistance is a term used in electricity to describe opposition to current flow. An amount of resistance is measured in ohms (Ω) with an ohmmeter. All materials offer resistance to current flow but differences in atomic structure allow some materials to have more resistance than others.

Materials that have high resistance to current flow are known as insulators. Air, rubber, and plastic are examples of insulators. It is interesting to note that even the best insulators will conduct current if the amount of electrical pressure is high enough. Materials that have low resistance are known as conductors. Copper, aluminum and mercury are examples of conductors.

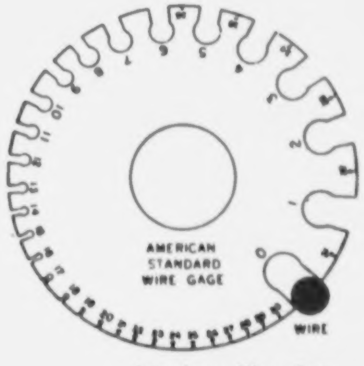
Similarities exist between a water system and an electrical system. In a water system, water flow is limited by the size of the pipe. A small diameter pipe or a long length of pipe offers a lot of resistance and as a result only a small amount of water can flow through it. In an electrical system, current flow is limited by the size of the wire and by the electrical devices in the circuit. A small diameter wire offers a lot of resistance and as a result only a small amount of electrical current can flow through it.

## ELECTRICAL WIRING PRACTICES

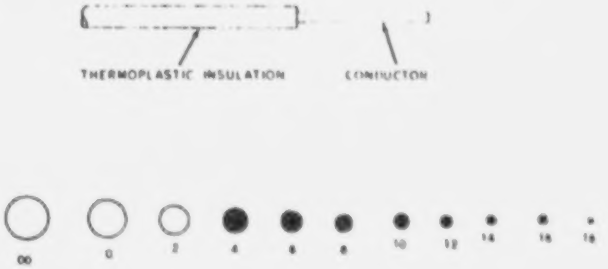
In the repair of heating equipment, the technician must sometimes choose from a variety of different wire sizes; each designed for certain conditions and each capable of carrying a limited amount of current. Too large a conductor may involve unnecessary installation expenses while too small a wire might create a fire hazard or poor equipment performance. The right choice is always a wire large enough to carry the electrical load safely.

The National Electrical Code book should be consulted to determine which wire size should be used for a particular load. This reference book contains complete information such as wire current capacity, circuit overload protection and other subjects related to safe wiring practices. For those unfamiliar with its use, the final chapters provide examples of how it can be used and also indicates where information can be located in the book. Recognized nationally by all Air Force and civilian authorities, this book should be used as a guide for all electrical wiring practices.

Wire size can be measured by using the American Wire Gauge (AWG). The figure below shows a picture of the gauge. Wire is measured by determining the smallest opening the conductor will pass through the slots on the side without binding. Each opening is numbered to indicate the corresponding wire size. The larger the wire, the smaller the number used to represent the wire size. The gauge is normally not necessary when checking new wire because most wire manufactured today has the wire size printed on it.



American Wire Gage



Conductor Size Without Insulation

Each wire size has the ability to carry a limited amount of current. The chart below shows the maximum safe current capacity for copper and aluminum wire at different sizes up to 50 feet in length.

| WIRE SIZE | CURRENT CAPACITY OF WIRE (AMPERES) | |
|---|---|---|
| (AWG) | COPPER | ALUMINUM |
| No. 14 | 15 | - |
| No. 12 | 20 | 15 |
| No. 10 | 30 | 25 |
| No. 8 | 40 | 30 |

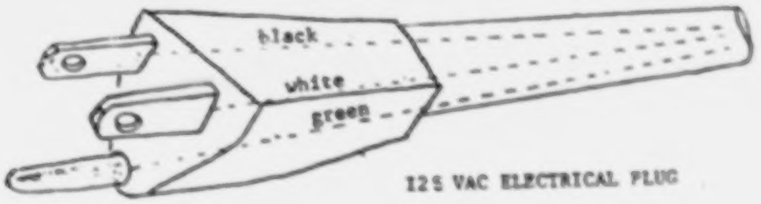
The wire size is the minimum gauge that should be used for the amperage listed. Lengths greater than 50 feet require a larger wire size.

Wire Size and Current Capacity

PROBLEM: Find the maximum current capacity of a number 14 AWG copper wire.

SOLUTION: The maximum current capacity of a number 14 AWG copper wire is 15 amps.

All replacement wire used on electrical equipment should be the same type, size and color as the original. Using the proper wire color helps to standardize wiring procedures and also aids in identifying and tracing wires. Installers of line voltage wiring (above 50 volts AC), have generally accepted that green or bare conductors are used for ground wires, white is used to represent grounded neutral wires and other colors are used to represent the "hot" wires.

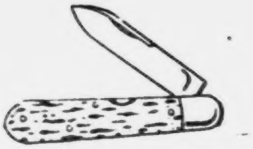


125 VAC ELECTRICAL PLUG

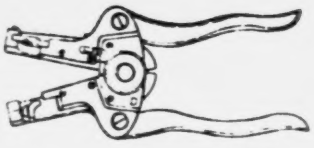
To make repairs on heating equipment, it is sometimes necessary for you to make various types of connections or splices. Normally, screw terminals, soldered splices, or mechanical connectors of some sort are used to connect wires to switches, motors, appliances, and so on.

All electrical connections must be mechanically and electrically secure...A poor electrical connection can cause a fire or serious damage to the equipment. Electrical connections must conduct electricity as easily as a continuous wire.

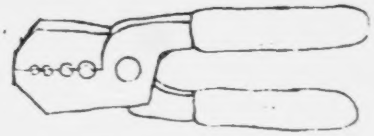
Before a wire or cable can be attached to a device, there should be no insulation at the point of connection. As you gain experience, the removal of the proper amount of insulation for each connection will become automatic. A knife is generally used to remove insulation from large wires, however, for small wire a wire stripping tool or wiring tool may be used. When you remove insulation from a wire, be careful that you do not cut into the wire itself. A nick may cause the wire to break after it is installed. A deep nick or scratch reduces the current carrying capacity of the wire. After the insulation is removed, the wire may be burnished (scraped) with a knife or fine sandpaper to remove any bits of insulation and oxidation remaining on the wire.



Electrician's Knife

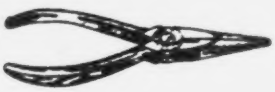


Wire Stripper

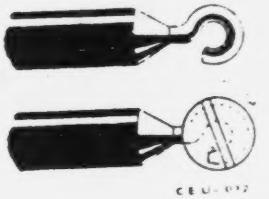


Wiring Tool

When connecting wire to screw terminals, use long nose pliers to form a loop or eye in the bare end of the wire. Examine the screw-terminal loop below. Notice how the loop is placed around the screw. As the screw is tightened, it tends to close the loop. If the wire is not placed on the screw in this manner, the loop tends to open when the screw is tightened. When making this type of connection, the insulation must cover the wire close to the terminal. Too much exposed wire becomes hazardous and can cause electrical problems.

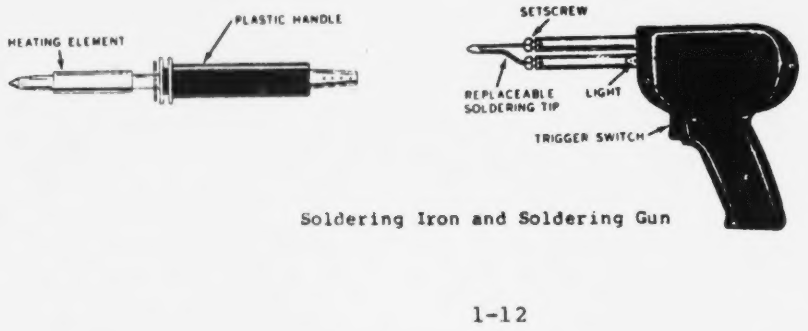


Long Nose Pliers



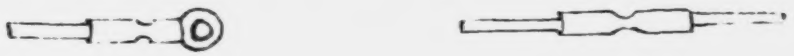
Screw-Terminal Loop

Soldered connections are sometimes used to join wires. Soldering involves the joining of metals by adding another metal to bond them together. Electrical work requires solder composed of 60% lead and 40% tin with a resin core. The resin is used as a flux to clean the metal as it is joined; other types of flux will cause corrosion. Heat is applied to the joint to be soldered by either a soldering gun or soldering iron. The figures below show examples of a soldering iron and a soldering gun. Once a soldered splice has been made, it must be insulated with electrical tape to prevent the bare wires from touching the metal box and causing electrical trouble. Electrical tape should be applied in layers to provide the same amount of insulation as the insulation on the remainder of the wire.



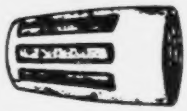
Soldering Iron and Soldering Gun

New crimp type wire connectors are becoming popular for service and repair work. Wires are stripped then inserted into the metal sleeve of the connector then crimped with a wiring tool. Care should be taken not to cut through the outer plastic covering.



Solderless "crimp" connectors

Another method of joining wires involves the use of spring type connectors commonly called "wire nuts." This type of connector uses a plastic cap with a metal spring inside. When the bare ends of two or more wires are inserted into the connector and the wire nut twisted, the spring firmly grips the wire and makes a good electrical contact.



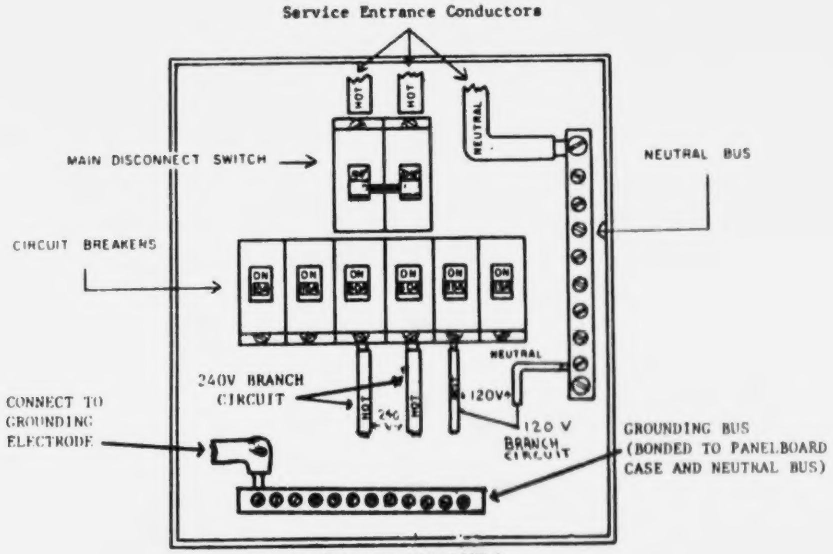
Wire Nut

Special wire connectors are required when joining aluminum and copper conductors. The use of improper connectors for these two dissimilar metals will lead to fire or equipment failure.

The techniques used to make electrical connections often require practice but once mastered, a technician can make very quick, neat and safe connections.

## CONTROLLING ELECTRICITY

Electricity from the power company enters a building through the service entrance. If you look at a service entrance, you will probably see a number of wires coming from a nearby utility pole. The wires come down the side of the building inside a pipe to the electric meter. Just below the electric meter, they go through a wall of the building into the main service panel. The main service panel may consist of either main fuses or circuit breakers. As the power leaves the "main" it is distributed to separate individual branch circuits, each having its own fuse or circuit breaker.


Service Entrance Conductors
HOT
HOT
NEUTRAL
MAIN DISCONNECT SWITCH
NEUTRAL BUS
CIRCUIT BREAKERS
ON
ON
ON
ON
ON
ON
NEUTRAL
240V BRANCH CIRCUIT
HOT
240 V
HOT
120V
120 V BRANCH CIRCUIT
CONNECT TO GROUNDING ELECTRODE
GROUNDING BUS (BONDED TO PANELBOARD CASE AND NEUTRAL BUS)

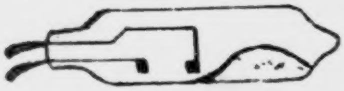
CIRCUIT BREAKER
PANELBOARD

The heating specialist is not involved with installation or maintenance of electrical distribution systems but does have a need to become familiar with the operation of electrical devices that are used to control heating equipment. This lesson is designed to help you understand how electricity can be controlled by switches, fuses and circuit breakers.

Switches

A switch is one of the simplest devices used to control electricity. The purpose of a switch is to start and stop current flow. Mercury and snap-action type switches are commonly used to control heating equipment.

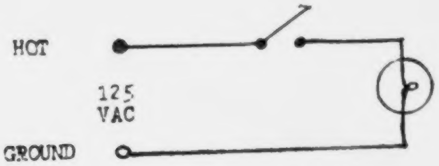
snap-action switch


mercury switch

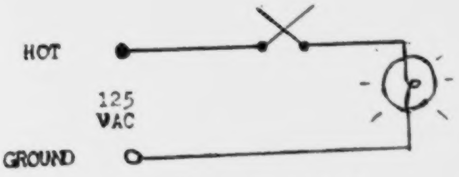
Snap-action switches vary in design. Some are made so that the movement of a lever causes a spring or magnet to move the switch contacts with "snap-action." The contacts of some snap-action switches may be cleaned (if accessible) by using special spray contact cleaners, burnishing tools, or crocus cloth. Care must be taken not to damage switch contacts by improper cleaning. Dirty or improperly cleaned contacts will lead to eventual switch failure.

Mercury switches have electrical contacts and a small amount of mercury sealed in a glass tube. Tilting the tube causes the mercury to cover or uncover the switch contacts. CAUTION: Mercury is a toxic substance and should not be handled!

Electrical current will flow through a switch when the contacts are in the closed or "on" position. When the contacts of a switch are in the open or "off" position, the air gap between the contacts will prevent current flow. Some switches are designed to be normally open (NO) or normally closed (NC). When replacing electrical switches, always replace them with the same voltage and amperage ratings as the original.



SWITCH OPEN (OFF)



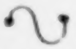
SWITCH CLOSED (ON)

Electrical switches are used in various types of heating controls such as:

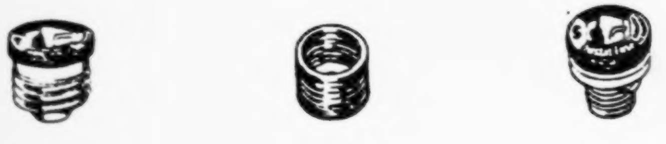
- Thermostats
- Aquastats
- Pilotstats
- Limit Controls
- Fan Controls
- Control Relays
- Motor Starters
- Feedwater Controls
- Pressure Controls
- Humidistats

Circuit Protective Devices

Fuses and circuit breakers are designed to protect circuits from too much current flow. A circuit with too much current flow will become overheated and may become a serious fire hazard. The voltage and the current of the circuit being protected will determine the type and size of fuse or circuit breaker used. All circuit protective devices are rated in volts and amps and are designed to be the weakest "link" in an electrical circuit.

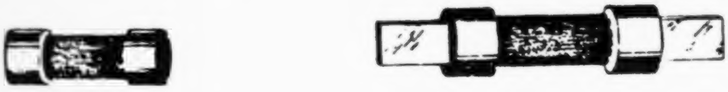
Fuses: 

There are several different types of fuses; each containing a fusible link that will melt or "blow" if too much current is applied. One type of fuse is called a "plug" or screw type fuse. A plug fuse contains a fusible link enclosed within a housing which is screwed into a socket similar to a lamp socket. They provide overload protection to circuits of 125 volts or less and are restricted to currents of up to 30 amps.


EDISON BASE
ADAPTER
TYPE S

Plug Fuses and Adapter

Cartridge type fuses contain a fusible link enclosed within an insulated cartridge housing with conductive metal ends designed to clip or "snap" into a fuse holder. Cartridge fuses are available in various voltage and amperage ratings. Fuses of the same amperage rating but different voltage will vary in length; the higher the voltage, the longer the fuse. When a fuse "blows," the resulting air gap must have enough resistance to stop current flow. Cartridge type fuses are either renewable or nonrenewable. A blown nonrenewable fuse must be replaced; a renewable fuse can be disassembled and the blown link replaced.


CARTRIDGE FUSE WITH
FERRULE CONTACTS

CARTRIDGE FUSE WITH
KNIFE-BLADE CONTACTS

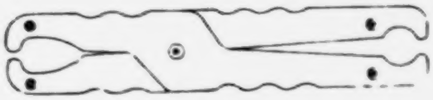
Cartridge Fuses

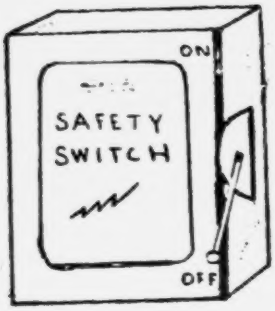
Some circuits require a time-delay fuse. Motor circuits often utilize fuses with a time-delay feature to allow the motor to momentarily draw an excessive amount of current necessary at start-up. Plug and cartridge type fuses are available with a time-delay feature.

Safe electrical practices must be followed when installing and replacing fuses. Electricians are responsible for the initial installation of fuses but the heating specialist may be called on to replace "blown" fuses.

A blown fuse indicates that something is wrong and the problem must be corrected. The proper selection of fuses can become complicated and might demand the attention of an electrician. If the blown fuse is known to be the right size and type then it must be replaced by an identical fuse.

Cartridge fuses are often found in fused safety switch boxes (fuse box). A special fuse puller is used to remove and install fuses.


Fuse puller.



When replacing fuses in a fused safety switch, the following procedures should be followed:

1. De-energize fused safety switch by moving the switch handle to the OFF position. (CAUTION: A portion of the safety switch will still be "hot" even with the switch in the off position.)

2. Perform a visual inspection of the safety switch:

   a. Construction features
   b. Maximum amperage rating of switch
   c. Type and amperage rating of fuses
   d. Electrical connections
   e. Cleanliness

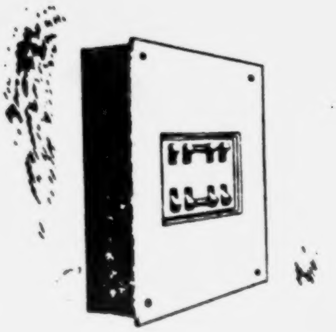
3. Grasp each fuse with fuse puller and remove them from the fuse holders.

4. Select replacement fuses.

5. Install each replacement fuse into the fuse holders. A distinctive "snap" will be heard and felt to indicate that the fuse is secure.

## Circuit Breakers

Circuit breakers are overload devices designed to automatically trip or open the circuit at a predetermined amperage without injury to itself. When it opens a circuit it can be reset by moving a handle, pushing a button or other device. There are many types of circuit breakers.

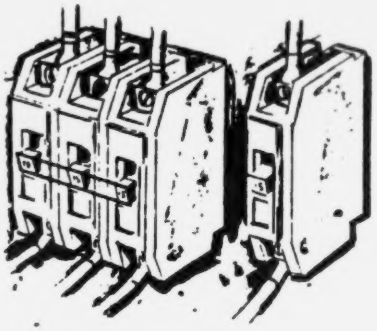


Circuit breaker panel

One type of circuit breaker is the thermal type. It uses a bimetallic strip as its trip device. As current flows through this strip or is heated indirectly by current flowing in a heater coil, the bimetallic strip bends. When the strip bends, it releases a catch allowing a spring-activated mechanical device to operate. As the mechanical device actuates, it opens a set of contacts and stops current flow. The circuit breaker will now have to be reset to reclose the contacts and allow current to flow.

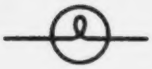
The bimetallic strip in a 20 amp circuit breaker is designed to carry 20 amps of current without heating enough to bend. If 21 amps of current should flow through the strip, it would begin to heat and slowly bend eventually releasing the catch. A larger overload tends to overheat the bimetallic strip quicker, releasing the catch faster.

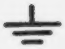
A tripped circuit breaker indicates that something is wrong and the problem must be corrected. Heating specialists are sometimes called on to reset circuit breakers but the installation and maintenance of circuit breakers is performed by electricians.

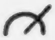


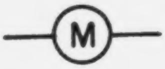
## COMMON ELECTRICAL SYMBOLS USED IN ELECTRICAL DIAGRAMS

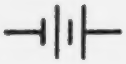
NOTE: Electrical symbols are used to represent components used in electrical equipment. In the heating career field you will be examining diagrams of equipment produced by a variety of different companies. While you should learn the common symbols on this page, keep in mind that some manufacturers use symbols that are different from those shown. Many electrical diagrams have legends to let you know what each symbol represents.

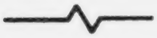

lamp

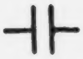

ground

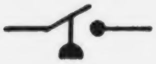

circuit breaker

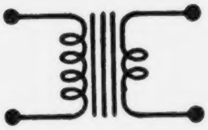

AC motor

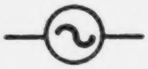

battery

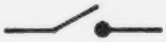

coil

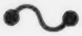

normally open contacts

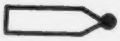

pressure switch

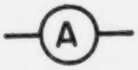

transformer

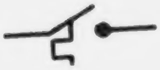

AC generator

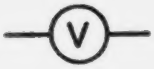

SPST switch
(single pole-single throw)

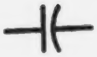

fuse

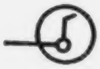

thermocouple/thermopile

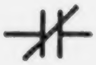

ammeter


temperature switch


voltmeter


capacitor


electrode


normally closed contacts

## SUMMARY

Observance and endorsement of safety rules will prevent accidents and improve working conditions. Accident prevention is a part of all operations, not a separate job. Each person is responsible for observing safety rules and trying to prevent accidents. Rules cannot be written to cover every instance, good judgement by all personnel is essential.

Scientists have broken down matter into more than 100 different substances called elements. The smallest part of an element is the atom. An atom is made up of protons, neutrons and electrons. An electron has a negative electrical charge.

Under normal conditions, atoms are balanced. Atoms that have become unbalanced are electrically charged. An atom that has gained electrons is considered to be negative. An atom that has lost electrons is considered to be positive.

The Electron Theory states that electrical current will flow from a negative charge to a positive charge.

Voltage is the electrical energy or "electron moving force" produced by negative and positive electrical charges. Several devices can be used to produce voltage by changing some form of energy into electrical energy. A thermocouple converts heat energy into electrical energy, a battery converts chemical energy into electrical energy, while a mechanical generator converts mechanical energy into electrical energy.

Current is a term used to describe the rate of electron flow from a negative to a positive electrical charge. The amount of current flow through a wire is measured in amps. Direct current travels in one direction, while alternating current travels in alternating directions.

Insulators have a high amount of resistance to current flow while conductors have low resistance. Air, rubber and plastic are examples of insulators. Copper, aluminum and mercury are examples of conductors.

The National Electrical Code (NEC) book is used as a reference for determining wire current capacity, circuit overload protection and other subjects related to safe wiring practices. Each wire size has the ability to carry a limited amount of current. All replacement wire used on electrical equipment should be the same type, size and color as the original. All electrical connections must be mechanically and electrically secure.

Switches, fuses and circuit breakers are used to control electricity. All devices used to control electricity have maximum voltage and amperage ratings. Switches are designed to start and stop current flow. Two common types of electrical switches are the "snap-action" and mercury type. A switch in the open position is "off" while a switch in the closed position is "on."

Fuses and circuit breakers are designed to protect circuits from too much current flow. A circuit is a complete path for current flow. A circuit with low resistance will have high current flow. An excessive amount of current will cause fuses to "blow" or circuit breakers to trip. A blown fuse or tripped circuit breaker indicates something is wrong and the problem must be corrected.

# THEORY OF MAGNETISM AND TRANSFORMERS

OBJECTIVE:

Given information, identify basic facts relating to the theory of magnetism and transformers, by correctly answering 70% of the questions.

INTRODUCTION:

In this unit you will receive practical information concerning electromagnetic devices used in heating systems including solenoid valves, control relays, low voltage control transformers and high voltage ignition transformers.

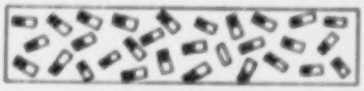
The material in this unit is presented under the following main topics:

- MAGNETISM
- ELECTROMAGNETISM
- SOLENOID VALVES
- CONTROL RELAYS
- TRANSFORMERS

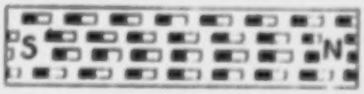
INFORMATION:

## MAGNETISM

Magnetism refers to the ability of an object to attract materials that contain iron. One theory explains that all matter is made up of tiny magnetized particles. If the magnetized particles are arranged in the same direction, the material is considered to be magnetized.



NON-MAGNETIZED



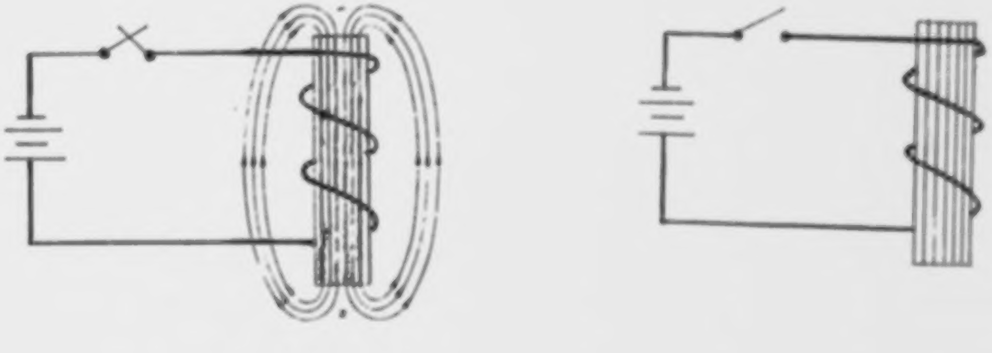
COMPLETELY MAGNETIZED

The invisible magnetic force surrounding a magnet is called a magnetic field. Magnetic fields are made up of "lines of force." Magnets have two areas of highly concentrated lines of force called poles. Each one has a north and south pole. On the outside of a magnet, lines of force extend from the north pole toward the south pole. When two of them are placed together; like poles will repel while unlike poles will attract.

The ability of a magnet to affect an object is known as induction. Magnetism can be induced into some materials by placing them in a magnetic field. If the material is removed from the magnetizing field and continues to be magnetized, it is considered to be a permanent magnet; if not, the material was only temporarily magnetized.

## ELECTROMAGNETISM

Magnetism produced by electricity is called electromagnetism. When electric current flows through a conductor, a magnetic field is produced. If the amount of current through a conductor were increased, the magnetic field would increase. The magnetic field can also be increased by coiling or "looping" the conductor and by placing an iron core inside of the coil. To be useful, electromagnets are designed to be only temporarily magnetized. A specially designed iron core placed in an electromagnetic coil will lose its magnetism when the current flow stops and the magnetic field disappears.

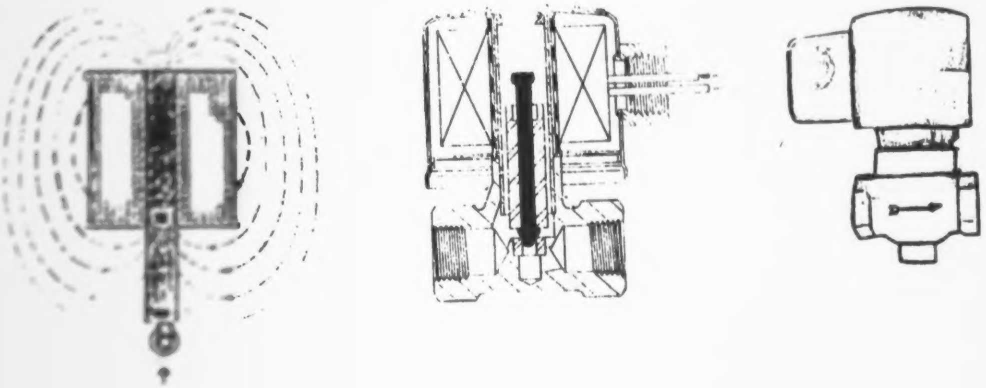


Electromagnet

## SOLENOID VALVES

A solenoid valve is an electrically operated valve designed to control the flow of water, oil, or gas.

A basic solenoid consists of a coil of wire, an iron plunger, a spring, and a valve body.



Solenoid action, internal view and picture of solenoid valve

When a solenoid coil is energized, it will produce magnetism that will attract a moveable iron plunger; allowing water, oil, gas (or other substance) to flow through the valve body. When the coil is de-energized, the plunger will fall back into the valve body to shut off the flow. The spring will help to prevent the valve from leaking.

Most solenoid valve problems can be placed under one of four categories:

- valve will not open
- valve will not close
- valve is noisy (commonly caused by a lack of voltage)
- valve coil has no continuity (burned out)

Solenoid valves are designed with a special purpose in mind. Read the data plate on replacement solenoid valves to determine what it was designed to do.

Typical Solenoid Valve Data Plate:

CLICKER SOLENOID VALVE CO.

24 VAC 60 Hz

.6A

FOR GAS USE ONLY

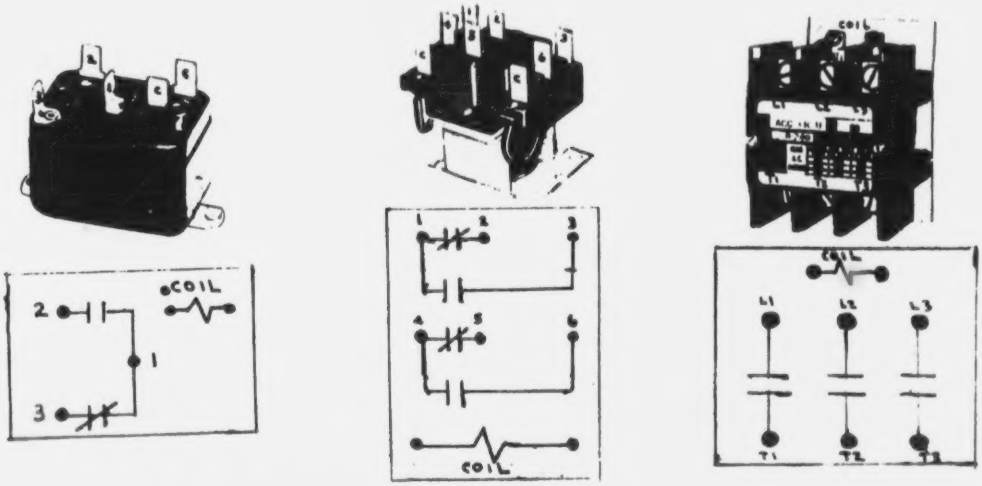
...This solenoid valve requires 24 VAC, 60 Hz

...This solenoid valve is expected to have .6 amps of current when energized.

## CONTROL RELAYS

A control relay is an electrically operated switch.

A basic relay consists of a coil of wire, an iron armature, a spring and switch contacts.



Control Relays and Connection Diagrams

When a relay coil is energized, it will produce magnetism that will attract a moveable armature; opening or closing the contacts. A relay that has contacts in the open position (when the coil is de-energized) is considered to be normally-open (NO). The opposite holds true for a normally-closed (NC) relay. Some relays have both normally-open and normally-closed contacts.

Most control relay problems can be placed under one of four categories.

--contacts will not open
--contacts will not close
--relay is noisy (commonly caused by lack of voltage)
--coil has no continuity (burned out)

There are many applications for control relays in heating systems. Relays are available in many different types, sizes and shapes. Heavy-duty relays are sometimes called magnetic contactors. Always check the data plate to determine the coil operating voltage, the current rating of the switch contacts, and other information that might be useful.

Typical Control Relay Data Plate:

CLICKER RELAY CO.

coil: 24VAC 50/60 Hz .5A

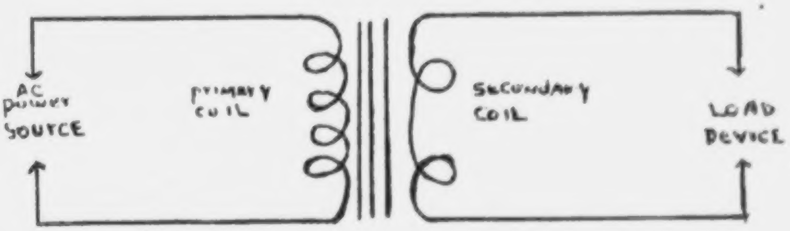
contact rating: 4 amps at 120 VAC
2 amps at 240 VAC

...This relay requires 24 VAC, and will operate at 50 or 60 Hz.

## TRANSFORMERS

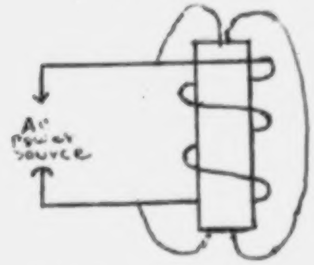
In order to supply the correct amount of voltage for some equipment, it is sometimes necessary to step the available voltage down or step it up. A device that changes alternating current from one voltage to another is called a transformer.

A basic transformer consists of two separate coils of wire. The primary coil of a transformer is connected to the power source. The secondary coil is connected to the load device it supplies power to.

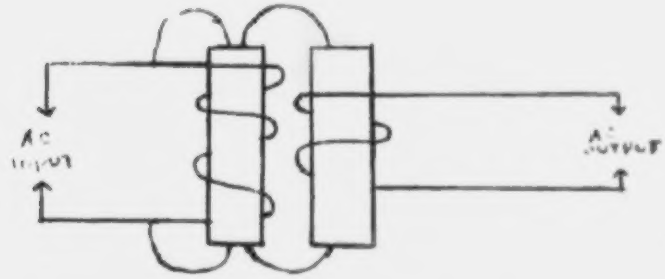


Theory of transformer operation:

When an alternating current flows through a coil of wire, an alternating magnetic field is produced around the coil. If an iron core is placed inside the coil, the magnetic field will be concentrated on each end to form magnetic poles.

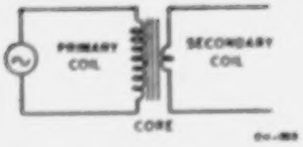


If a second coil of wire is placed in an alternating magnetic field, the magnetic field will pass or "cut" through it. The energy of this moving magnetic field causes electrons in the second coil of wire to move in alternating directions. A transformer has the ability to transform or change moving magnetic energy into electrical energy.

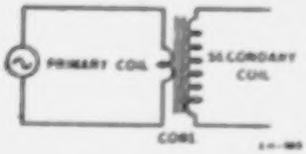


Transformer ratios

The ratio of turns or loops in the primary and secondary coils will determine whether the transformer output voltage will be "stepped down" or "stepped up." A transformer that has a fewer number of turns in the secondary will step voltage down. A transformer that has a higher number of turns in the secondary will step the voltage up.


PRIMARY COIL
SECONDARY COIL
CORE

Step-Down Transformer

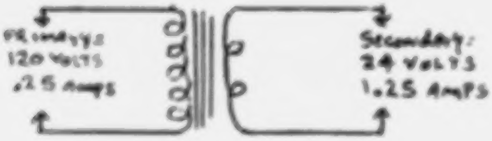

PRIMARY COIL
SECONDARY COIL
CORE

Step-Up Transformer

A transformer does not produce free electricity. The power that can be delivered by a transformer will be relatively the same as the amount of power it consumes.

PROBLEM 1 How much wattage does this transformer consume?

PROBLEM 2 How much wattage can this transformer deliver?


PRimary:
120 Volts
.25 Amps
Secondary:
24 Volts
1.25 Amps

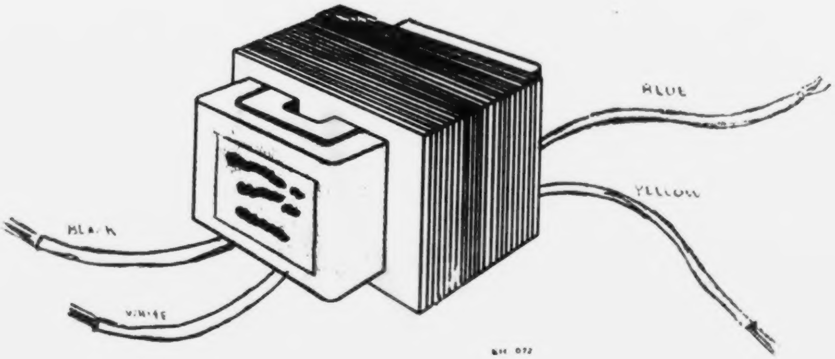
SOLUTION 1 This transformer consumes 30 watts. (120 volts X .25 amps)

SOLUTION 2 This transformer can deliver 30 watts. (24 volts X 1.25 amps)

# COMMON TRANSFORMERS USED IN HEATING SYSTEMS

## Low Voltage Control Transformers

Low voltage control transformers step voltage down to approximately 24 volts. The output of this type of transformer is used as a power source for low voltage control circuits (under 50 VAC). Low voltage circuits are safer than line voltage circuits.



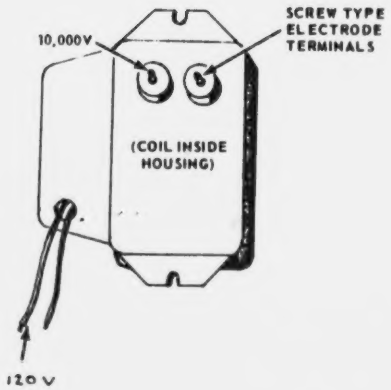
Low Voltage Control Transformer

Typical Low Voltage Control Transformer Data Plate:

| BUZZ TRANSFORMER CO. | |
|---|---|
| PRI 120 VAC 60 Hz<br>Bk-Wht | .....This transformer requires 120 VAC, 60 Hz. connected to the black and white primary leads. |
| SEC 24 VAC 60 Hz<br>Blu-Yel | .....This transformer has a 24 VAC, 60 Hz. output on the blue and yellow secondary leads. |
| 30 VA (VOLT/AMPS) | .....The maximum amount of power this transformer is designed to deliver is 30 watts. |
| Class II UL Listed | .....This transformer meets the requirements for a class II electrical system (control voltage power supply) and has passed certain safety requirements of Underwriters Laboratory. |

## High Voltage Ignition Transformers

High voltage ignition transformers step voltage up to approximately 10,000 volts. The output of this type of transformer is used to ignite fuel with an electrical arc.


10,000V
SCREW TYPE ELECTRODE TERMINALS
(COIL INSIDE HOUSING)
120 V

Typical High Voltage Ignition Transformer Data Plate:

ZAP TRANSFORMER CO.

PRI: 120 VOLTS 60 HERTZ

SECONDARY: 10,000 VOLTS

23 M.A.

.....The maximum current output of this transformer is 23 milli-amps (.023 amps).

## SUMMARY

Any material attracted by a magnet is a magnetic material. The ability of an object to attract iron or steel is known as magnetism. The invisible magnetic force surrounding a magnet is known as the magnetic field. Unlike poles of a magnet attract. A magnetic material is believed to consist of millions of tiny magnets. Some materials become magnetized when in a magnetic field. If the material is no longer magnetized when the magnet is taken away, the materials are considered to be temporary magnets.

Magnetism produced by electricity is known as electromagnetism. When electric current flows through a conductor, a magnetic field is produced. An electromagnetic device becomes a magnet when energized. When the current flow through an electromagnet stops, it will lose its magnetism.

An electrical device that is designed to control the flow of water, oil or gas is known as a solenoid valve.

A control relay is an electrically operated switch. The moving part of a relay is known as an armature. A relay that has contacts in the open position when the relay coil is not energized is considered to be normally open.

A device that changes alternating current from one voltage to another is a transformer. The primary coil of a transformer is connected to the power source. The secondary coil of a transformer is connected to the load device. A transformer that has a higher number of turns of wire in the secondary coil is considered to be a "step-up" transformer. A low-voltage control transformer steps voltage down. A high-voltage ignition transformer steps voltage up.

## NOTES

# TYPES AND CHARACTERISTICS OF ELECTRICAL CIRCUITS

## OBJECTIVES:

Given information, identify basic facts relating to types and characteristics of electrical circuits by correctly answering 70% of the questions.

Using electrical circuit trainer, construct electrical circuits, with a maximum of two instructor assists.

## INTRODUCTION:

In this unit you will learn the requirements for an electrical circuit and the fundamental law; Ohm's law which describes its operation. You will also learn how to make calculations involving basic electrical circuits. The calculations will enable you to determine the amounts of resistance, current, voltage, and power consumption to expect in an actual operating circuit. Lastly, you will learn how to connect simple, series, parallel and series-parallel circuits on a trainer.

The material in this unit is presented under the following main topics:

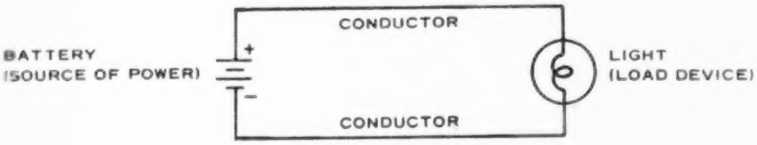
- BASIC ELECTRICAL CIRCUITS
- OHM'S LAW FOR DC CIRCUITS
- CHARACTERISTICS OF SERIES AND PARALLEL CIRCUITS

## INFORMATION:

### BASIC ELECTRICAL CIRCUITS

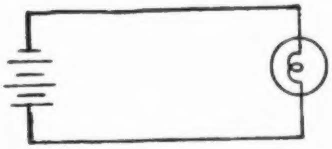
An electrical circuit is a complete path for current flow. The three basic requirements of an electrical circuit are:

- Source of power
- Conductors
- Load device

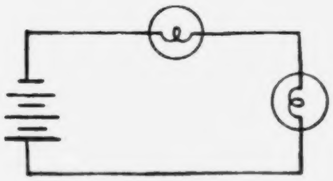


Electrical circuits can be divided into four general types; simple, series, parallel, and series parallel.

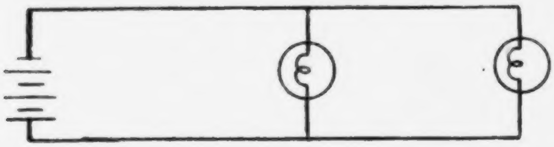
- SIMPLE CIRCUIT...One path for current and one load device.



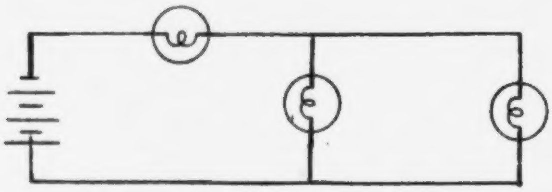
- SERIES CIRCUIT...One path for current and two or more load devices.



- PARALLEL CIRCUIT...Two or more paths for current with one load device in each path.



- SERIES-PARALLEL CIRCUIT...Combination of series and parallel circuits.



## OHM'S LAW FOR DC CIRCUIT

In the early 1800's, Professor George Ohm, published the results of his research in electricity. Using instruments invented and built by himself, Professor Ohm had discovered a mathematical relationship between voltage, current and resistance in an electrical circuit. Ohm summarized his work with equations which are now referred to as Ohm's Law. Ohm's Law is used to make predictions concerning voltage, current and resistance in an electrical circuit.

In Ohm's Law equations, the letters E, I, and R are used to represent the three electrical factors of an electrical circuit. The letter E is used to represent the electron moving force (measured in volts), the letter I represents the intensity of current flow (measured in amps), and the letter R represents the resistance to current flow (measured in ohms).

Ohm's Law can be represented by these equations:

E = I X R            I = E / R            R = E / I

These three equations will enable you to find any one of the three factors (voltage-current-resistance) if you know the other two. An easy way to remember the three relationships is to place them in a circle as shown in figure 3-1.

If you place your finger over the factor that is not known, the relative position of the others will indicate what to do. If one is above the other, divide. If they are alongside each other, such as I and R, then multiply.

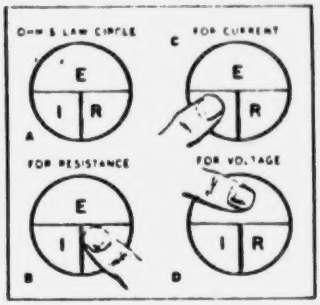

OHM'S LAW CIRCLE
FOR CURRENT
FOR RESISTANCE
FOR VOLTAGE
A
B
C
D
E
I
R

Figure 3-1. Ohm's Law Chart

PROBLEM 1: Use Ohm's Law to determine the amount of voltage supplied by the battery in figure 3-2.

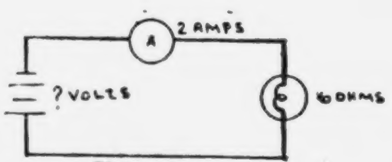

A
2 AMPS
? VOLTS
6 OHMS

Figure 2 2

SOLUTION: E = I X R

E = 2 X 6

E = 12 volts

PROBLEM 2: Use Ohm's Law to determine the amount of current flow through the circuit in figure 3-3.

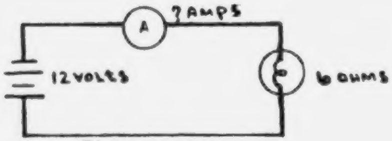

A
? AMPS
12 VOLTS
6 OHMS

Figure 2 3

SOLUTION: I = E / R

I = 12 / 6

I = 2 amps

PROBLEM 3: Use Ohm's Law to determine the amount of resistance in the circuit shown in figure 3-4.

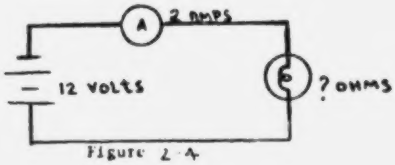

A
2 AMPS
12 VOLTS
? OHMS

Figure 2 4

SOLUTION: R = E / I

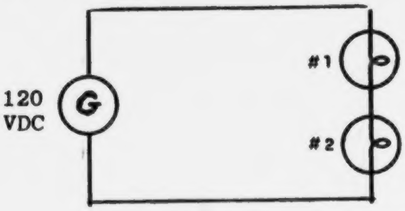
R = 12 / 2

R = 6 Ohms

## CHARACTERISTICS OF SERIES AND PARALLEL CIRCUITS

Characteristics of series load circuits:

1. The sum of the voltage measured across each load device will equal the total applied voltage.
2. The same amount of current will flow throughout the circuit.
3. The sum of the resistances of each load device will equal the total resistance.

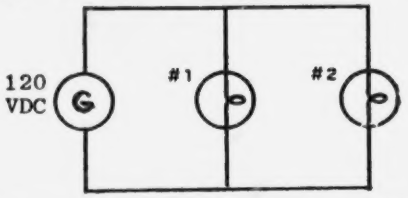


| | | | |
|---|---|---|---|
| E | 80 | 40 | 120 |
| I | 2 | 2 | 2 |
| R | 40 | 20 | 60 |
| | lamp 1 | lamp 2 | TOTAL |

a. The voltage consumed by lamp 1 is 80 volts.
b. The voltage consumed by lamp 2 is 40 volts.
c. Total applied voltage to this circuit is 120 volts.
d. The amount of current flow through lamp 1 is 2 amps.
e. The amount of current flow through lamp 2 is 2 amps.
f. Total current flow through the entire circuit is 2 amps.
g. The resistance of lamp 1 is 40 ohms.
h. The resistance of lamp 2 is 20 ohms.
i. The combined resistance of this circuit is 60 ohms.

Characteristics of parallel load circuits:

1. Each load device will receive the same amount of voltage.
2. The total amount of current in the circuit represents the sum of the current flow through each path.
3. The total resistance of the circuit is always less than any individual resistance.



| | | | |
|---|---|---|---|
| E | 120 | 120 | 120 |
| I | 2 | 4 | 6 |
| R | 60 | 30 | 20 |
| | lamp 1 | lamp 2 | TOTAL |

a. The voltage consumed by lamp 1 is 120 volts.
b. The voltage consumed by lamp 2 is 120 volts.
c. Total applied voltage to this circuit is 120 volts.
d. The amount of current flow through lamp 1 is 2 amps.
e. The amount of current flow through lamp 2 is 4 amps.
f. Total current flow through the entire circuit is 4 amps.
g. The resistance of lamp 1 is 60 ohms.
h. The resistance of lamp 2 is 30 ohms.
i. The combined resistance of this circuit is 20 ohms.

SUMMARY

An electrical circuit is a complete path for current flow.

The three basic requirements of an electrical circuit are:

- source of power
- conductors
- load device

The four general types of circuits are:

- simple
- series
- parallel
- series-parallel

A simple circuit has one path for current and one load device.

A series circuit has one path for current and two or more load devices.

A parallel circuit has two or more paths for current with one load device in each path.

A series-parallel circuit is a combination of series and parallel circuits.

Ohm's law can be used to mathematically calculate any one of the three electrical factors (voltage-current-resistance) if any two factors are known. $E = I \times R$ $I = E/R$ $R = E/I$.

Characteristics of series load circuit:

E = SUM
I = SAME
R = SUM

Characteristics of parallel load circuit:

E = SAME
I = SUM
R = LESS

# ELECTRICAL WIRING DIAGRAMS

OBJECTIVE:

Using electrical drawings, trace electrical circuits to determine operating characteristics, by correctly answering 70% of the questions.

INTRODUCTION:

An electrical diagram is an electrical drawing used to represent circuits used in electrical equipment. There are many types of electrical diagrams; each designed to serve as a "roadmap" of electrical components. Electrical diagrams are often used to show the arrangement and/or relationship of each component used in the actual equipment. It is important to be able to interpret these drawings because they can be useful as a guide for the installation, repair, and maintenance of various electrical equipment.

The material in this unit is presented under the following main topics:

- ELECTRICAL DIAGRAMS
- TRACING ELECTRICAL DIAGRAMS

INFORMATION:

## ELECTRICAL DIAGRAMS

There are basically four types of electrical diagrams. These drawings are similar to each other and their names are sometimes used interchangeably, but they do have differences. The four types of electrical diagrams are the block diagram, wiring diagram, connection diagram and the schematic diagram.

BLOCK DIAGRAM: A block diagram is a simple drawing showing the relationship of major parts of a system. Figure 4-1 shows a block diagram of a motor control system. You can easily see why it is called a block diagram. The parts or component in any block diagram will be shown just as they appear in this drawing, as blocks. The internal connections of the components are not shown in these drawings. The blocks are simply labeled to show what each represents.

WIRING DIAGRAM: The wiring diagram, which is like a picture drawing, shows the wiring between components and the relative position of the components in the equipment. The second diagram from the left in figure 4-1 shows a wiring diagram of the same motor control system shown by the block diagram. You can see that instead of blocks used to show components, a picture of the component is used.

CONNECTION DIAGRAM: The third diagram shown in figure 4-1 is a connection diagram. It makes use of diagram symbols instead of pictures to show components. It also shows all the internal and external circuit connections, and shows the components in their relative position. This diagram can be used to help you connect all the wiring and trace any part of the circuit, which makes it a valuable guide for servicing equipment.

SCHEMATIC DIAGRAM: The schematic diagram is a drawing that shows the electrical plan of operation of a piece of electrical equipment or component. The relative position of parts is not shown in this type of diagram. The schematic diagram, like the connection diagram, makes use of symbols instead of pictures. The schematic diagram in figure 4-1 is a plan of the same motor control system in the other three diagrams. It is laid out so that the components are in line to make it easy to trace the operation of the system.

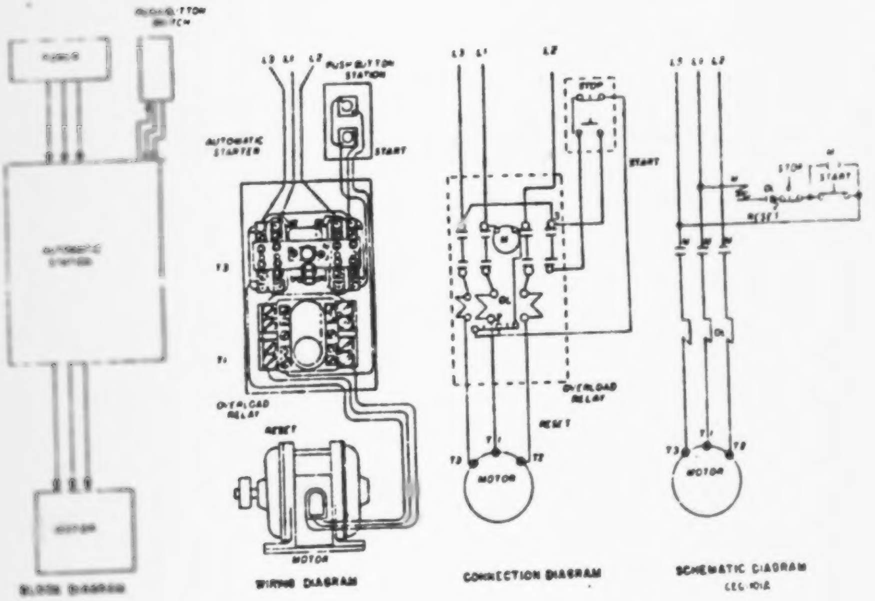

PUSHBUTTON SWITCH
AUTOMATIC STARTER
MOTOR
BLOCK DIAGRAM
L3 L1 L2
PUSH-BUTTON STATION
AUTOMATIC STARTER
START
T3
T1
OVERLOAD RELAY
RESET
MOTOR
WIRING DIAGRAM
L3 L1 L2
STOP
START
M
OL
OVERLOAD RELAY
RESET
T1
T3
T2
MOTOR
CONNECTION DIAGRAM
L3 L1 L2
M
STOP
START
OL
RESET
M
T3 T1 T2
MOTOR
SCHEMATIC DIAGRAM
LEC 1012

Figure 4-1. Electrical Diagrams

Electrical drawings are often found on inside covers of electrical equipment. Be careful not to lose or damage these drawings. Replacement drawings for old equipment may not be available. Drawings for newer equipment can be ordered from the manufacturer but cause unnecessary expenses and waiting time.

# TRACING ELECTRICAL DIAGRAMS

Technicians attempting to make emergency repairs on electrical equipment are often frustrated because the diagrams nearly always seem to be too confusing. Careful study of a diagram requires a great deal of time and patience. It is important to examine diagrams or drawings of equipment you are required to service BEFORE it becomes necessary.

Electrical diagrams can be compared to a road map. When you plan a trip from California to Texas you would study only the areas that immediately concern you. The same approach could be used when studying an electrical diagram.

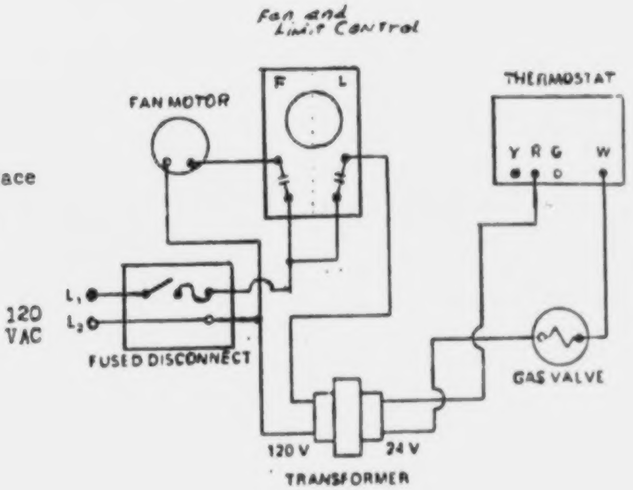
Circuits used in electrical equipment are often given names that describe what the circuit will do. If a circuit is used to operate a blower motor then the whole circuit could be called a "blower circuit." Other circuits might be called burner circuits, circulating pump circuits, etc.

When you look at an electrical diagram you need to decide which circuit you are concerned with. Once you have chosen a circuit then you should examine the diagram to answer questions like these: What is the load device in this circuit? What does the load device do? What voltage does the load device need? Where is the power source? How much voltage does the power source provide? How is the load device controlled?

If you can answer the previous questions, then you can "trace" an electrical diagram. You can avoid panic while tracing electrical diagrams by remembering: "A WIRE HAS ONLY TWO ENDS."

Domestic Furnace

Diagram

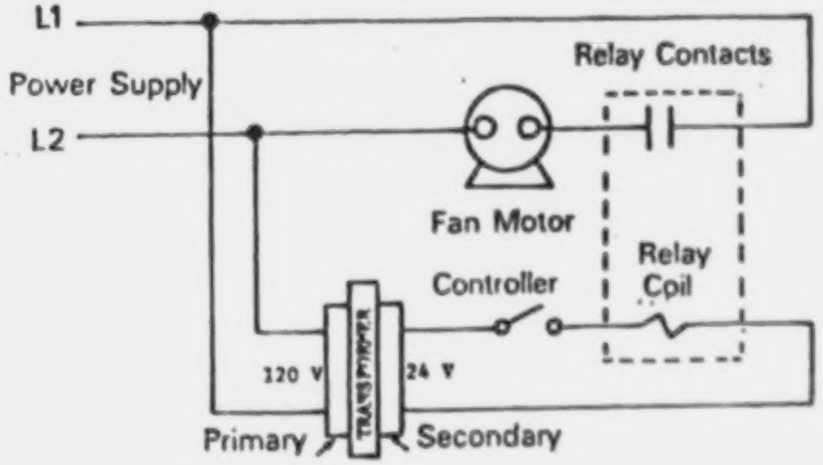


BURNER CIRCUIT:

The load device on this circuit is the gas valve. The gas valve is an electrically operated valve designed to allow gas to flow to a burner when it is energized by 24 volts. The transformer needs 120 volts (input) in order to provide 24 volts (output). Power applied to the transformer is controlled by the limit control. The fused disconnect is used to disconnect power to the circuit and to help protect it from overloading.

BLOWER CIRCUIT:

The load device on this circuit is the fan motor. The fan motor is a motor with a fan blade on it designed to "blow" air when energized by 120 volts. Power to the fan motor is controlled by the fan control. The fused disconnect is used to disconnect power to the circuit and to help protect it from overloading.


L1
Power Supply
L2
Relay Contacts
Fan Motor
Relay Coil
Controller
120 V
TRANSFORMER
24 V
Primary
Secondary

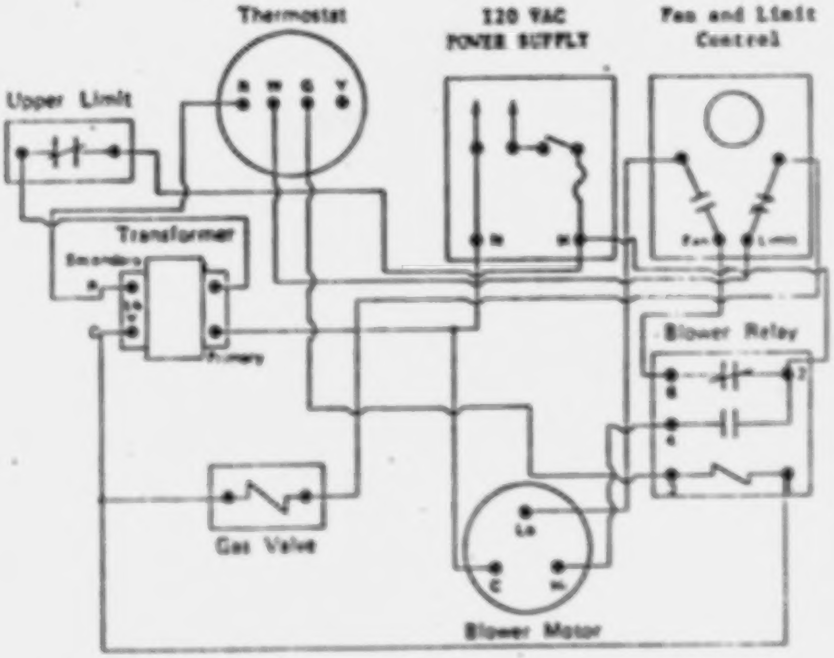
Fan relay circuit

BLOWER CIRCUIT:

The load device on this circuit is the fan motor. The fan motor is a motor with a fan blade on it designed to "blow" air when energized by 120 volts. Power to the fan motor is controlled by the relay contacts.

RELAY CIRCUIT:

The load device on this circuit is the relay coil. The relay coil causes the relay contacts to close when energized by 24 volts. The relay coil is controlled by a controller switch. The transformer needs 120 volts (Primary) in order to provide 24 volts (Secondary). The transformer in this diagram is connected to $L_1$ and $L_2$ of the power supply.


Thermostat
120 VAC
POWER SUPPLY
Fan and Limit
Control
Upper Limit
R
W
G
Y
Transformer
Secondary
R
C
Primary
N
H
Fan
Limit
Blower Relay
2
6
4
Gas Valve
Lo
C
Hi
Blower Motor

Warm Air Furnace Diagram

BURNER CIRCUIT:

The load device on this circuit is the gas valve. The gas valve needs 24 volts to operate. The gas valve is controlled by the limit control and the thermostat switch (terminals R and W). The transformer supplying power to the gas valve is controlled by the upper limit switch. Power to energize the transformer comes from the 120 VAC power supply.

BLOWER CIRCUIT:

The load device on this circuit is a two speed blower motor operated by 120 VAC.

- LOW SPEED is controlled by the fan control.

- HIGH SPEED is controlled by the blower relay.

RELAY CIRCUIT

The load device on this circuit is the relay coil (terminals 3 and 5). The relay coil is controlled by the thermostat (terminals R and G). The relay coil causes relay contacts 2 and 6 to open and contacts 2 and 4 to close when energized by 24 volts from the transformer. The transformer supplying power to the relay coil is controlled by the upper limit switch. Power to energize the primary of the transformer comes from the 120 VAC power supply.

## SUMMARY

An electrical diagram is an electrical drawing used to represent circuits used in electrical equipment. There are many types of electrical diagrams; each designed to serve as a "roadmap" of electrical components. Electrical diagrams are often used to show the arrangement and/or relationship of each component used in the actual equipment. It is important to be able to interpret these drawings because they can be useful as a guide for the installation, repair, and maintenance of various electrical equipment.

There are basically four types of electrical diagrams. These drawings are similar to each other and their names are sometimes used interchangeably, but they do have differences. The four types of electrical diagrams are the block diagram, wiring diagrams, connection diagrams and schematic diagrams.

Electrical symbols are used to represent components used in electrical equipment. In the heating career field you will be examining diagrams of equipment produced by a variety of companies. While you should learn the symbols in this unit, keep in mind that some manufacturers use symbols that are different than those presented here. Many electrical diagrams have legends to let you know what each symbol represents.

Technicians attempting to make emergency repairs on electrical equipment are often frustrated because the diagrams nearly always seem too confusing. Careful study of a diagram requires a great deal of time and patience. It is important to examine diagrams or drawings of the equipment you are required to service BEFORE it becomes necessary.

Electrical diagrams can be compared to a road map. When planning a trip you would study only the areas that immediately concern you. The same approach applies when studying an electrical diagram.

Circuits used in electrical equipment are often given names that describe what the circuit will do. If a particular circuit is used to operate a blower motor then the whole circuit could be called a "blower circuit." Other circuits might be called burner circuits, circulating pump circuits, etc.

When examining an electrical diagram you need to decide which circuit you are concerned with. Once you have chosen a particular circuit then you should examine the diagram to answer questions like these: What is the load device on this circuit? What does the load device do? What voltage does the load device need? Where is the power source? How much voltage does the power source provide? How is the load device controlled?

If you can answer the previous questions; then you can "trace" an electrical diagram. You can avoid panic while tracing electrical diagrams by remembering: "A WIRE HAS ONLY TWO ENDS."

## NOTES

# ELECTRICAL TEST EQUIPMENT

OBJECTIVES:

Using multimeter, select, care and use ohmmeter function (continuity) by correctly identifying the resistance characteristics of 70% of the electrical devices.

Using multimeter, select, care and use voltmeter function by correctly identifying the voltage characteristics of 70% of the electrical devices.

Using multimeter, select, care and use ammeter function by correctly identifying amperage characteristics of 3 out of 4 electrical devices.

INTRODUCTION:

In this unit you will learn to use electrical test equipment. You will be using a multimeter that is easy to use and is gaining popularity in the heating career field. The multimeter can function as a voltmeter, ohmmeter or ammeter. You will get "hands on" training using the multimeter in a realistic setting.

The material in this unit is presented under the following main topics:

- ELECTRICAL TEST EQUIPMENT
- OHMMETER
- VOLTMETER
- AMMETER

INFORMATION:

## ELECTRICAL TEST EQUIPMENT

A multimeter is a valuable tool used to diagnose malfunctions in electrical equipment. The multimeter can be used to identify defective electrical components or to check operating characteristics of electrical circuits. Without a multimeter, a technician might spend hours troubleshooting electrical equipment and would probably have to resort to a costly game of installing several new parts in an attempt to repair the equipment. The proper use of a multimeter allows a technician to narrow electrical troubles down to specific defective components; eliminating guesswork.

Multimeters are delicate, expensive instruments and must be handled with care. Avoid dropping, bumping, excessive heat or dampness. Special operating and storage instructions come with each meter. When taking a reading with a multimeter, look at it "face to face;" viewing the pointer from an angle will give an inaccurate reading. If the meter has a pointer locking device, always keep it locked when the meter is not being used to protect it from damage. A multimeter that is used and cared for properly can last several years. Intentional or accidental misuse of a meter can cause damage to the instrument and injury to the user.

This unit of instruction is designed to familiarize you with one particular type of electrical test equipment. Keep in mind that there are many different types of test equipment available. The multimeter we will use in this course can function as an ohmmeter (Ω), a voltmeter (V), and ammeter (A).

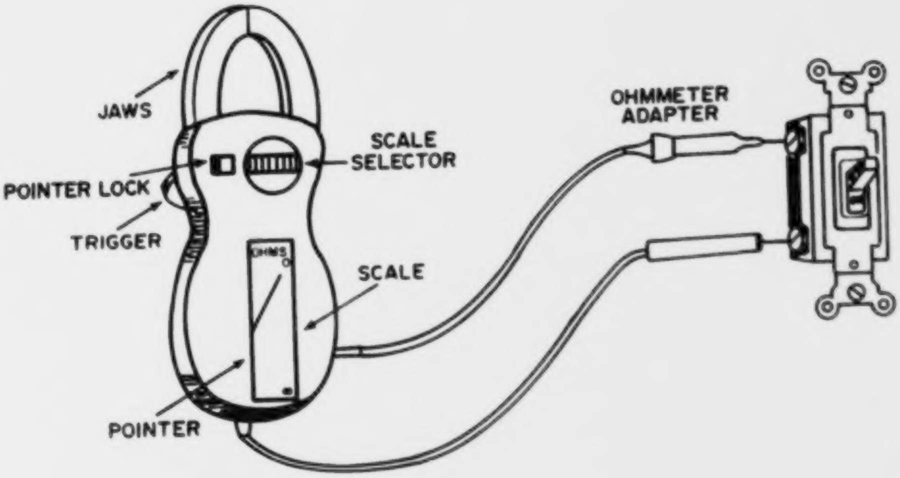
## OHMMETER

An ohmmeter can be used to measure resistance of circuit components. The resistance of circuit components can vary anywhere from zero ohms (no measurable resistance) to infinity (an extremely high amount of resistance). The symbol used to represent infinity is $\infty$ . An ohmmeter must be zeroed before use. This is done by touching the meter leads together and adjusting the zeroing knob until the pointer lines up with zero.

Special ohmmeters are used when precision resistance measurements are needed. The heating specialist normally does not have a need for exact resistance measurements to solve common problems in electrical equipment.

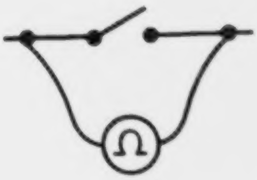
The importance of an ohmmeter to a heating specialist lies in its ability to be used simply to check continuity of electrical components. Continuity refers to a continuous, unbroken path for current flow. A quick, easy "continuity check" of a wire, fuse or switch will indicate if it is good or bad.

Any movement of an ohmmeter pointer indicates continuity. A wire, fuse, or switch (in the closed position) that does not have continuity is bad.



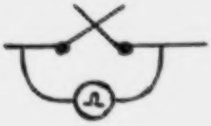
Determine "continuity" or "no continuity" of the following electrical components:

PROBLEM 1



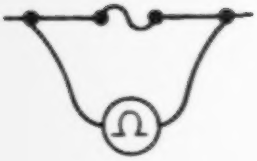
SOLUTION: NO CONTINUITY--An ohmmeter will indicate no continuity when connected to a switch in the open position.

PROBLEM 2



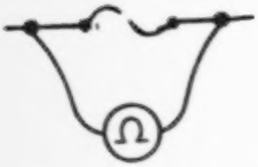
SOLUTION: CONTINUITY--An ohmmeter will indicate continuity when connected to a switch in the closed position.

PROBLEM 3



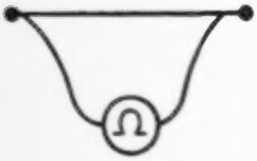
SOLUTION: CONTINUITY--An ohmmeter will indicate continuity when connected to a good fuse.

PROBLEM 4



SOLUTION: NO CONTINUITY--An ohmmeter will indicate no continuity when connected to a blown fuse.

PROBLEM 5



SOLUTION: CONTINUITY--An ohmeter will indicate continuity when connected to each end of a wire.

The meter uses a small 1.5 volt battery located in the ohmmeter attachment as a power supply. When both leads of the ohmmeter are connected together, a small amount of current begins to flow through the meter producing electromagnetism. This causes the pointer to move to the top of the scale. A properly calibrated ohmmeter will indicate zero ohms when the two test leads are connected together. When checking components with high resistance, don't be surprised if the pointer barely moves.

CAUTION: DO NOT CHECK AN ENERGIZED CIRCUIT OR COMPONENT WITH AN OHMMETER.

Since the ohmmeter provides its own source of power, any additional power from a component being checked could cause damage to the meter and injury to the user.

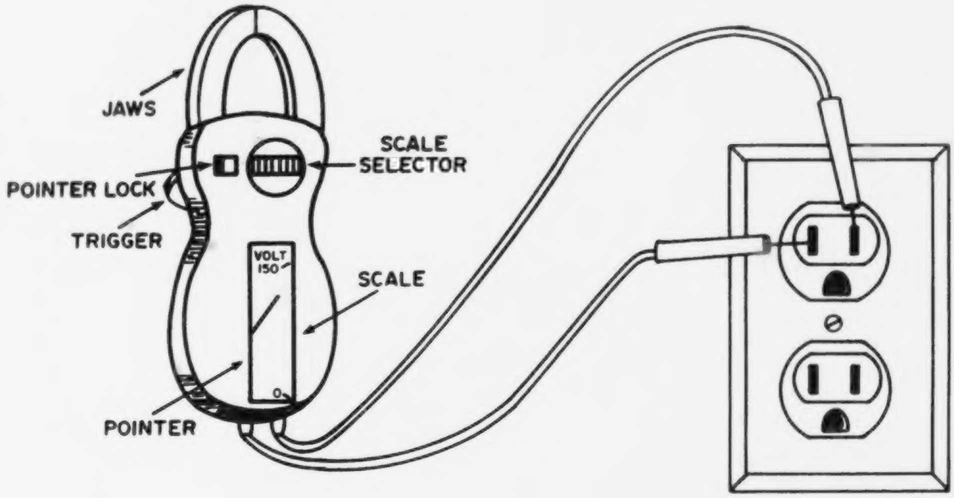
When using the ohmmeter it is always best to isolate the component being checked from the rest of the circuit by removing it or disconnecting the wires to it. When checking wires, separate each wire to be checked by disconnecting them from other wires, etc.

NOTE: It is a good idea to use numbered wire markers to identify wires before disconnecting them to prevent confusion during re-installation.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |

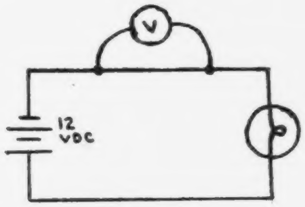
## VOLTMETER:

The voltmeter is a very useful instrument that can be used to measure the amount of voltage that exists between two test points in an electrical circuit. The pointer of a properly calibrated voltmeter will indicate zero volts when not in use.


JAWS
SCALE SELECTOR
POINTER LOCK
TRIGGER
VOLT 150
0
SCALE
POINTER

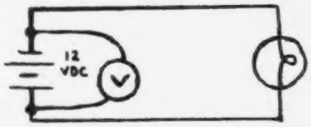
Determine the amount of voltage that exists between the two test points in each drawing:

PROBLEM 1



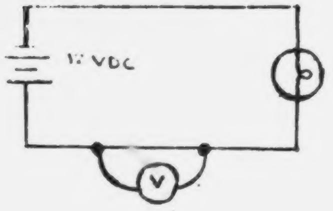
SOLUTION: ZERO VOLTS--A voltmeter connected negative to negative will not indicate voltage.

PROBLEM 2



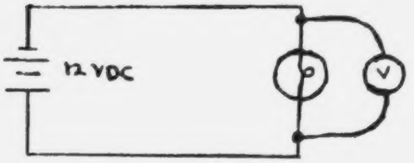
SOLUTION: 12 VOLTS--A voltmeter connected to negative and positive will indicate voltage.

PROBLEM 3



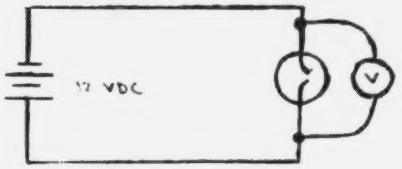
SOLUTION: ZERO VOLTS--A voltmeter connected positive to positive will not indicate voltage

PROBLEM 4



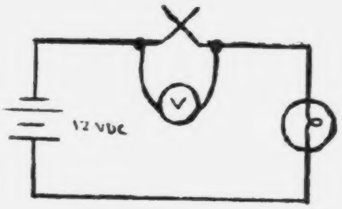
SOLUTION: 12 VOLTS-- A voltmeter connected to negative and positive will indicate voltage.

PROBLEM 5



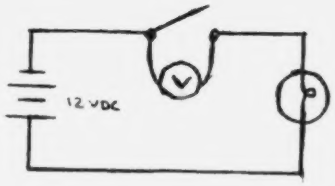
SOLUTION: 12 VOLTS--A voltmeter connected to negative and positive will indicate voltage.

PROBLEM 6



SOLUTION: ZERO VOLTS--A voltmeter connected negative to negative will not indicate voltage.

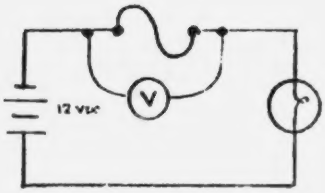
PROBLEM 7



SOLUTION: 12 VOLTS--A voltmeter connected to negative and positive will indicate voltage.

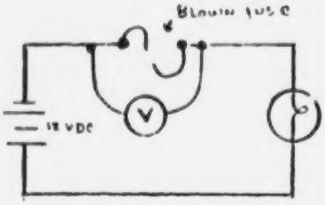
PROBLEM 8

SOLUTION: ZERO VOLTS--A voltmeter connected negative to negative will not indicate voltage.



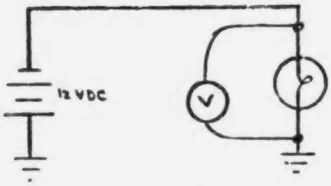
PROBLEM 9

SOLUTION: 12 VOLTS--A voltmeter connected to negative and positive will indicate voltage.


Blown fuse
12 VDC
V

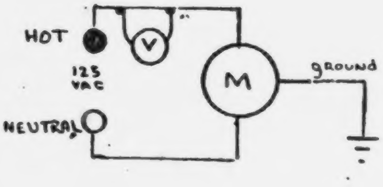
PROBLEM 10

SOLUTION: 12 VOLTS--A voltmeter connected to negative and positive will indicate voltage



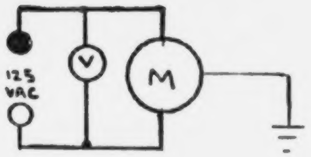
PROBLEM 11

SOLUTION: ZERO VOLTS--A voltmeter connected hot to hot of the same conductor will not indicate voltage. NOTE: The motor is grounded to help reduce the chance of electrical shock.

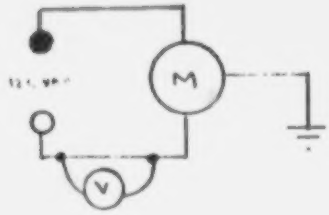

HOT
V
125 VAC
M
ground
NEUTRAL

PROBLEM 12

SOLUTION: 125 VOLTS--A voltmeter connected to hot and neutral will indicate voltage.

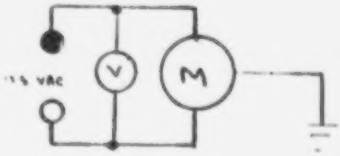


PROBLEM 13



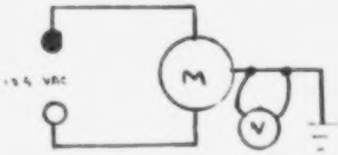
**SOLUTION:** ZERO VOLTS--A voltmeter connected neutral to neutral will not indicate voltage.

PROBLEM 14



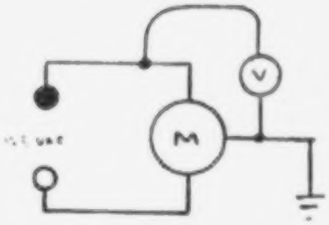
**SOLUTION:** 125 VOLTS--A voltmeter connected to hot and neutral will indicate voltage.

PROBLEM 15



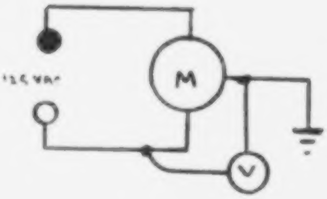
**SOLUTION:** ZERO VOLTS--A voltmeter connected ground to ground will not indicate voltage.

PROBLEM 16



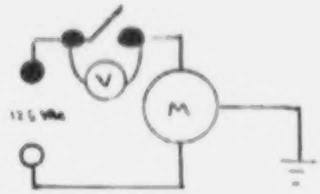
**SOLUTION:** 125 VOLTS--A voltmeter connected hot to ground will indicate voltage. NOTE: The ground wire is attached to the frame of the motor to help prevent electrical shock.

PROBLEM 17



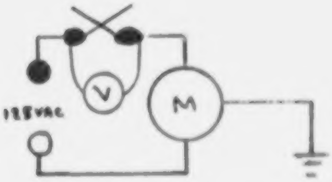
**SOLUTION:** ZERO VOLTS--A voltmeter connected to neutral and ground will not indicate voltage.

PROBLEM 18



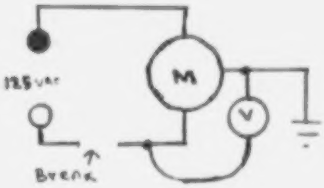
SOLUTION: 125 VOLTS--A voltmeter connected hot to neutral will indicate voltage.

PROBLEM 19



SOLUTION: ZERO VOLTS--A voltmeter connected hot to hot of the same conductor will not indicate voltage.

PROBLEM 20



SOLUTION: 125 VOLTS--A voltmeter connected hot to ground will indicate voltage.

The voltmeter has different voltage ranges available. The appropriate range is selected by turning the scale selector knob. If you do not know the voltage that is to be measured, always start with the highest range. The highest number in each range represents the highest voltage that can be measured.

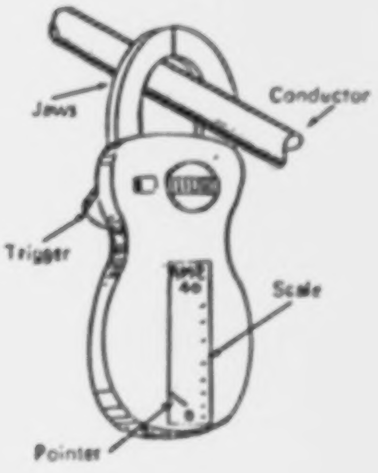
The meter will provide the most accuracy when the pointer is in the top half of the scale. Always try to pick a range that will provide the most accuracy but avoid checking voltage that is over the range shown on the scale. If it is set too low it could cause damage to the meter and injury to the user.

CAUTION: Always set the voltmeter on its highest range when measuring unknown voltage. Never use a damaged voltmeter. Hold the insulated portion of the test leads cautiously to prevent electrical shock. The metal probe on each test lead is sharp--don't poke yourself or anyone else.

Repair or maintenance work on electrical equipment is done with the power OFF but at times it is necessary to have the power on to check the amount of voltage being supplied to it. Never assume the power is off when servicing equipment. A voltmeter can be used to prove that the power is off before you begin service work and may save your life.

AMMETER

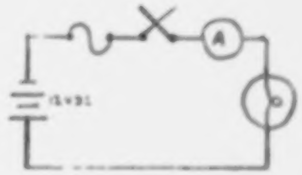
An ammeter can be used to measure the amount of current or amperage that flows through a circuit. The pointer of a properly calibrated ammeter will indicate zero amps when not in use.


Jaws
Conductor
Trigger
Scale
Pointer

Determine whether or not current would flow in each drawing:

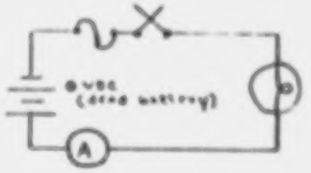
PROBLEM 1

**SOLUTION:** **CURRENT WILL FLOW--When voltage is applied to a complete, continuous circuit; current will flow.**

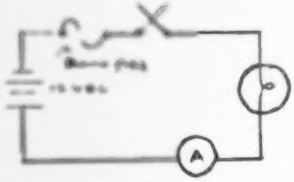


PROBLEM 2

**SOLUTION:** **CURRENT WILL NOT FLOW--Without voltage, current will not flow.**

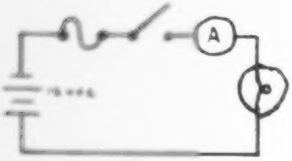

0 VDC
(dead battery)
A

PROBLEM 3



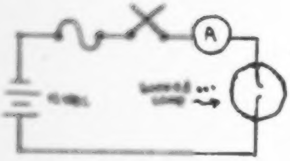
SOLUTION: CURRENT WILL NOT FLOW--A "blown" fuse will prevent current flow.

PROBLEM 4



SOLUTION: CURRENT WILL NOT FLOW--An "open" switch will prevent current flow.

PROBLEM 5



SOLUTION: CURRENT WILL NOT FLOW--A "burned out" lamp will prevent current flow.

The ammeter has different AMP ranges available. The range is selected by turning a dial. If you do not know what the amount of AMPs is to be measured, start with the highest range. The number at the top of each range represents the highest amperage that can be measured.

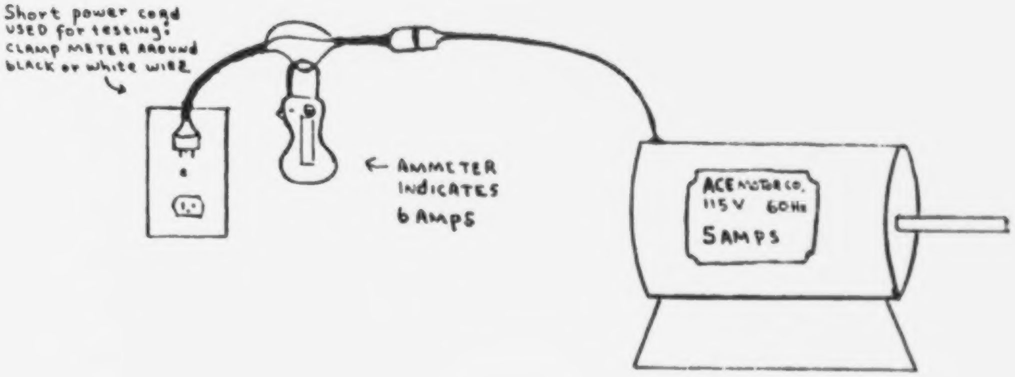
The ammeter will be most accurate when the pointer is in the top half of the scale. Always try to select a range that will provide the most accuracy, but avoid checking amperage that is over the range shown on the scale. If it is set too low, it could cause damage to the meter and injury to the user.

**CAUTION:** Always set the ammeter on its highest range when measuring an unknown amount of amperage. Never use a damaged ammeter.

To use the type of ammeter, we will be using, the jaws must be clamped around one current carrying conductor. Placing the ammeter jaws around two current carrying conductors will give an inaccurate reading.

An ammeter can be used to determine the operating efficiency of electrical equipment by comparing the actual amperage measured with the amperage rating listed on the equipment data plate. If the measured amperage is more than it should be, the equipment should be closely examined to determine the cause.

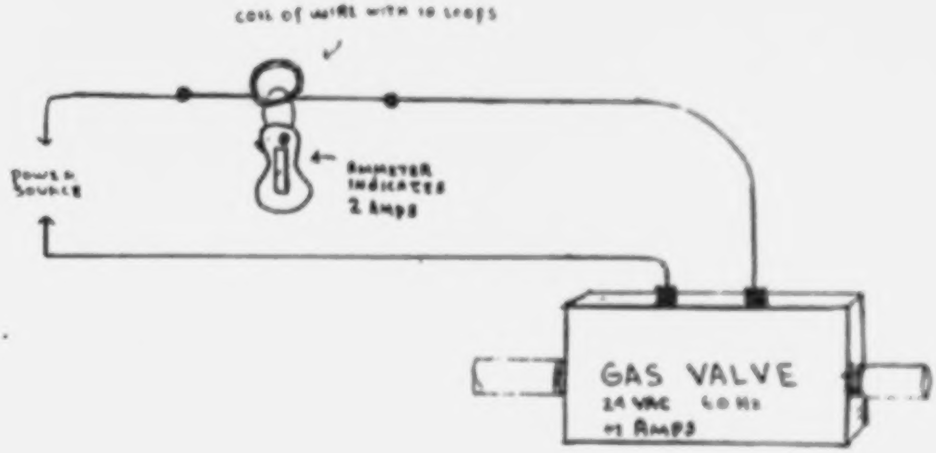
PROBLEM 6: Is the motor in the drawing operating efficiently?


Short power cord
USED for testing:
CLAMP METER AROUND
BLACK or white WIRE
← AMMETER
INDICATES
6 AMPS
ACE MOTOR CO.
115V 60Hz
5 AMPS

SOLUTION: NO--The amperage reading is higher than the amperage rating listed on the motor data plate. NOTE: The motor would be overheated from the excessive amount of current and would feel hot when touched.

When checking small amounts of current with the ammeter, the pointer will barely move. Since the pointer would be at the lower end of the scale, it would be difficult to get an accurate reading. The ammeter can be used to measure small amounts of current by attaching a coil of wire in series with the load device. The coil of wire will not have an effect on the circuit being checked, but will have a drastic effect on the ammeter. When the jaws of the ammeter are clamped around a coil of wire with 10 turns or "loops," the reading will be 10 times greater!

PROBLEM 7: How much amperage is flowing through the gas valve?



SOLUTION: 2 AMPS--The ammeter reading indicates 2 amps of current flow, but the gas valve has only .2 amps of current flowing through it. The ammeter reading must be divided by 10 to represent the amount of current flow through the gas valve.

## SUMMARY

A multimeter is a valuable tool used to diagnose malfunctions in electrical equipment. Multimeters are delicate, expensive instruments and must be handled with care. Intentional or accidental misuse of a meter can cause damage to the instrument and injury to the user.

The multimeter can function as an ohmmeter, voltmeter and ammeter.

-OHMMETER: An ohmmeter can be used to measure resistance of circuit components or to check continuity of electrical components. Continuity refers to a continuous, unbroken path for current flow. Do not check an energized circuit or component with an ohmmeter. When using the ohmmeter, it is best to isolate the component being checked from the rest of the circuit.

-VOLTMETER: The voltmeter is a very useful instrument that can be used to measure the amount of voltage that exists between two test points in an electrical circuit. Always try to select a range that will provide the best accuracy, but avoid checking voltage that is over the range indicated on the scale. If a voltmeter is "over ranged" it could cause damage to the meter and injury to the user. Always set the voltmeter on its highest range when measuring unknown voltage. Never use a damaged voltmeter. Hold the insulated portion of the test leads cautiously to prevent electrical shock. The metal probe on each test lead is sharp--don't poke yourself or anybody else.

-AMMETER: An ammeter can be used to measure the amount of current or amperage that flows through a circuit. Always try to select a range that will provide the most accuracy, but avoid checking amperage that is over the range indicated on the scale. If an ammeter is "over ranged," it could cause damage to the meter and injury to the user. Always set the ammeter on its highest range when measuring unknown amperage. Never use a damaged ammeter. The jaws of the ammeter must be clamped around one current carrying conductor. Placing the ammeter jaws around two current carrying conductors will give an inaccurate reading.

When taking a reading with a multimeter, look at it "face to face;" viewing the pointer from an angle will give an inaccurate reading. If the meter has a pointer locking device, always keep it locked when the meter is not being used to protect it from damage.

## NOTES

# ELECTRICAL MOTORS AND MOTOR STARTERS

OBJECTIVES:

Given information, identify basic facts relating to electrical motors and motor starters, by correctly answering 70% of the questions.

Using a trainer, remove and replace an electric motor, with a maximum of two instructor assists.

Using the single-phase and three-phase motor trainers, reverse motor rotation with a maximum of two instructor assists.

Using a three-phase motor trainer, inspect and maintain motor, with a maximum of two instructor assists.

INTRODUCTION:

In this unit you will be given information designed to prepare you for tasks that include installing, replacing, reversing rotation, inspection and maintenance of electrical motors.

The material in this unit is presented under the following main topics:

- BASIC CONSTRUCTION FEATURES OF ELECTRIC MOTORS
- THEORY OF OPERATION OF ELECTRIC MOTORS
- INTRODUCTION TO ELECTRIC MOTORS (TERMINOLOGY)
- MOTOR OVERLOAD PROTECTION
- MOTOR STARTERS
- MOTOR STARTERS WITH OVERLOAD PROTECTION
- SELECTING EXTERNAL OVERLOAD DEVICES
- MOTOR SAFETY
- MOTOR PROBLEMS AND CAUSES
- ELECTRIC MOTOR REMOVAL AND REPLACEMENT PROCEDURES
- ROTATION REVERSAL PROCEDURES
- ELECTRIC MOTOR INSPECTION AND MAINTENANCE PROCEDURES

# BASIC CONSTRUCTION FEATURES OF ELECTRIC MOTORS

The following figure represents the basic parts of an electric motor.

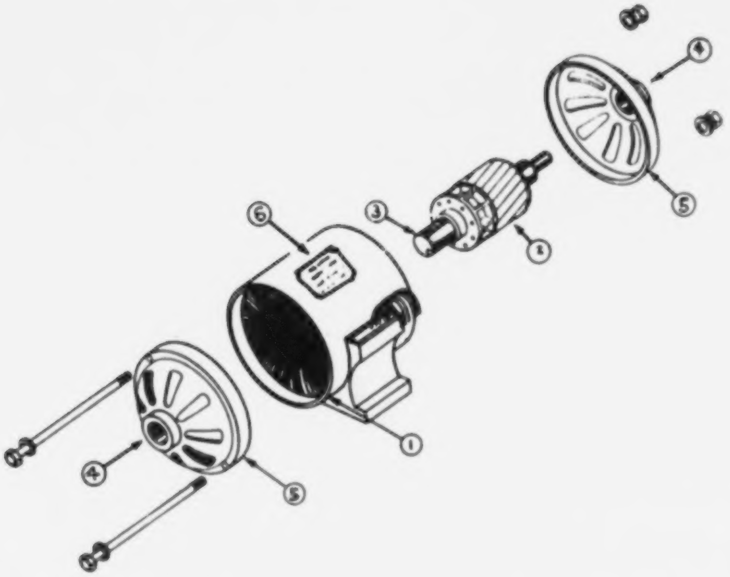


Figure 6-1. Components of an Electric Motor

1. STATOR - Stationary section of the motor that contains the windings and the electromagnetic core

2. ROTOR - Rotating section of the motor

3. SHAFT - Extension of the rotor which attaches to a fan, pump, etc.

4. MOTOR BEARINGS - Allow smooth rotation of the shaft

5. END BELLS - Portion of the motor that holds the bearings

6. DATA PLATE - Provides important information about the motor

# THEORY OF OPERATION OF ELECTRIC MOTORS

Electric motors are often compared to a transformer. The stator windings of the motor are thought of as the primary of a transformer, and the rotor is considered to be a rotating secondary. Current applied to the stator windings of the motor develops a strong magnetic field which produces magnetism in the rotor. The magnetic poles of the stator and the rotor are opposite at any given time, allowing *the forces of magnetism of* the stator to attract and repel the rotor.

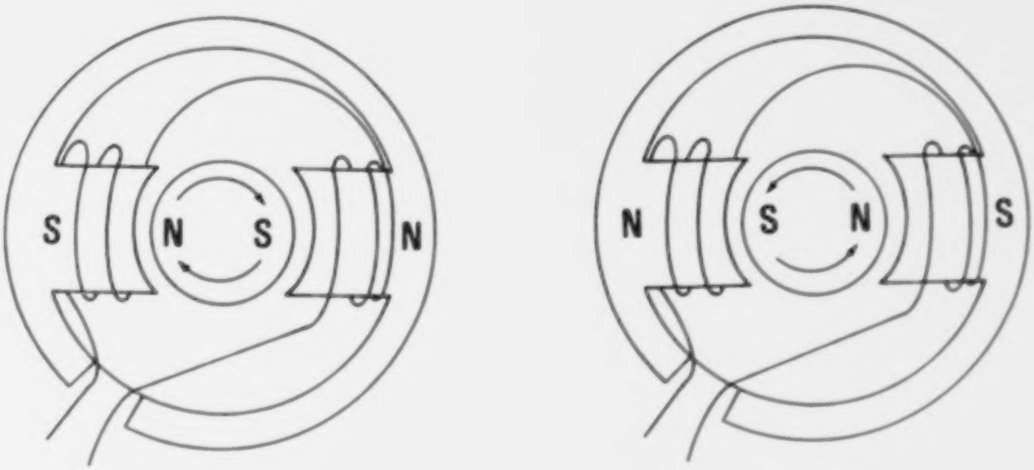


Figure 6-2. Reversing Direction of Current Flow Reverses Magnetic Polarity

# INTRODUCTION TO ELECTRIC MOTORS (TERMINOLOGY)

a. MOTOR--A device that changes electrical energy into rotating mechanical energy.

b. HORSEPOWER RATING--Amount of work a motor will do without damaging it.

c. PHASE--(Ph)-Designates the type of electrical power distributed to a motor; may be single-phase (1 Ø) or three-phase (3 Ø).

d. SINGLE-PHASE MOTOR--Alternating current motor with only two current carrying conductors.

e. THREE-PHASE MOTOR--Alternating current motor with three current carrying conductors.

f. SPLIT-PHASE MOTOR--A type of single-phase motor with start and run windings. While both windings are in use for starting the motor, the start winding is disconnected by a centrifugal switch after the motor reaches approximately 75% of its rated speed, then operates on the run winding only.

g. CAPACITOR MOTOR--A type of single-phase motor with similar construction to the split-phase type with the addition of a capacitor to enable it to operate under much heavier loads.

h. CAPACITOR--An electrical device capable of storing an electrical charge when power is applied to it. The electrical charge stored by a capacitor is used by capacitor motors to improve its operating characteristics. Two types of capacitors used commonly in heating equipment are known as start and run capacitors. A capacitor is rated in microfarads (μF). Replacement capacitors should be identical to the original. CAUTION: BEFORE HANDLING A START CAPACITOR IT SHOULD BE DISCHARGED WITH A BLEED RESISTOR.

j. LOCKED-ROTOR AMPERAGE (L.R.A.)--The amount of amperage consumed by a motor when it is first turned on.

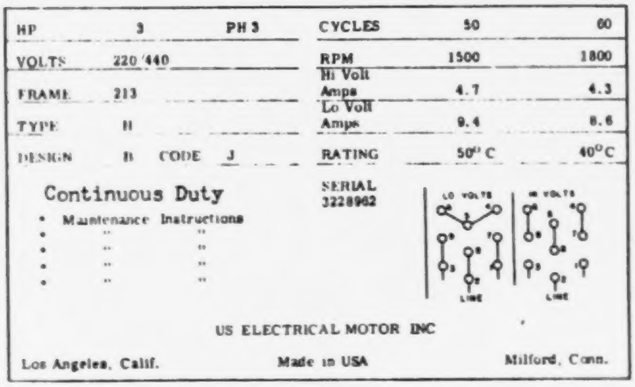
k. FULL-LOAD AMPERAGE (F.L.A.)--The amount of amperage consumed by a motor when it is delivering its rated horsepower.

l. REVOLUTIONS PER MINUTE (RPM)--Refers to the number of shaft rotations in one minute.

m. INSULATION CLASS--The type of insulation used on motor windings determine the maximum allowable operating temperature. (Examples: Class A...90°C Class B... 110°C Class H...150°C)

n. ROTATION--Refers to the clockwise or counter-clockwise rotation of a motor viewed from the shaft end of the motor or the end opposite the shaft. (Depending on the manufacturer)

o. MULTIPLE SPEED MOTOR--A motor which has the ability to operate at more than one speed.



HP 3 PH 3

VOLTS 220/440

FRAME 213

TYPE H

DESIGN B CODE J

CYCLES 50 60

RPM 1500 1800

Hi Volt Amps 4.7 4.3

Lo Volt Amps 9.4 8.6

RATING 50° C 40°C

Continuous Duty

- Maintenance Instructions
- " "
- " "
- " "
- " "

SERIAL
3228962

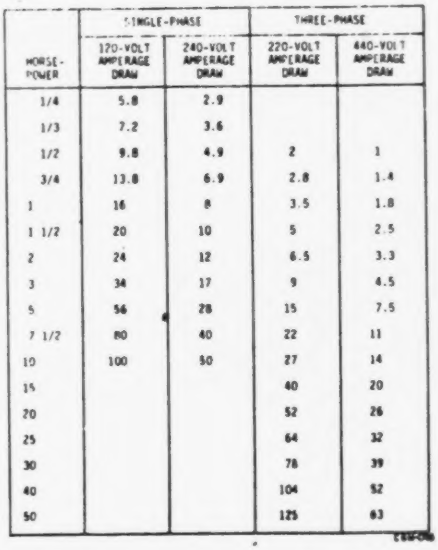
US ELECTRICAL MOTOR INC

Los Angeles, Calif. Made in USA Milford, Conn.

LO VOLTS
HI VOLTS
LINE
LINE

DO-082

Figure 6-3. Typical Motor Data Plate



| HORSE-POWER | SINGLE-PHASE | | THREE-PHASE | |
|---|---|---|---|---|
| | 120-VOLT AMPERAGE DRAW | 240-VOLT AMPERAGE DRAW | 220-VOLT AMPERAGE DRAW | 440-VOLT AMPERAGE DRAW |
| 1/4 | 5.8 | 2.9 | | |
| 1/3 | 7.2 | 3.6 | | |
| 1/2 | 9.8 | 4.9 | 2 | 1 |
| 3/4 | 13.8 | 6.9 | 2.8 | 1.4 |
| 1 | 16 | 8 | 3.5 | 1.8 |
| 1 1/2 | 20 | 10 | 5 | 2.5 |
| 2 | 24 | 12 | 6.5 | 3.3 |
| 3 | 34 | 17 | 9 | 4.5 |
| 5 | 56 | 28 | 15 | 7.5 |
| 7 1/2 | 80 | 40 | 22 | 11 |
| 10 | 100 | 50 | 27 | 14 |
| 15 | | | 40 | 20 |
| 20 | | | 52 | 26 |
| 25 | | | 64 | 32 |
| 30 | | | 78 | 39 |
| 40 | | | 104 | 52 |
| 50 | | | 125 | 63 |

Figure 6-4. Motor Horsepower and Amperage Draw

## MOTOR OVERLOAD PROTECTION

All electric motors need overload protection to help prevent them from "burning out." Special heat sensitive overload protectors are more sensitive than fuses and circuit breakers and are designed to automatically disconnect a motor if it gets too hot. Some overload protective devices are installed internally within the motor by the manufacturer. A motor with internal overload protection will usually have the following words printed on the data plate......"THERMALLY PROTECTED."

Some internal overload devices will automatically "reset" once an overheated motor returns to normal temperature, others have to be reset manually by pushing a reset button. NOTE: If a motor overheats, something is wrong and the problem must be corrected. Internal overload devices can fail and still allow a motor to "burn up."

## MOTOR STARTERS

Motor starters provide a safe, convenient and economical means of starting and stopping motors. Fractional horsepower motors (less than 1 H.P.) often use nothing more than a toggle switch to start and stop.

The on-off operation of large motors is sometimes controlled by magnetic contactors. When a magnetic contactor is used to start and stop an electrical motor it is considered to be a motor starter.

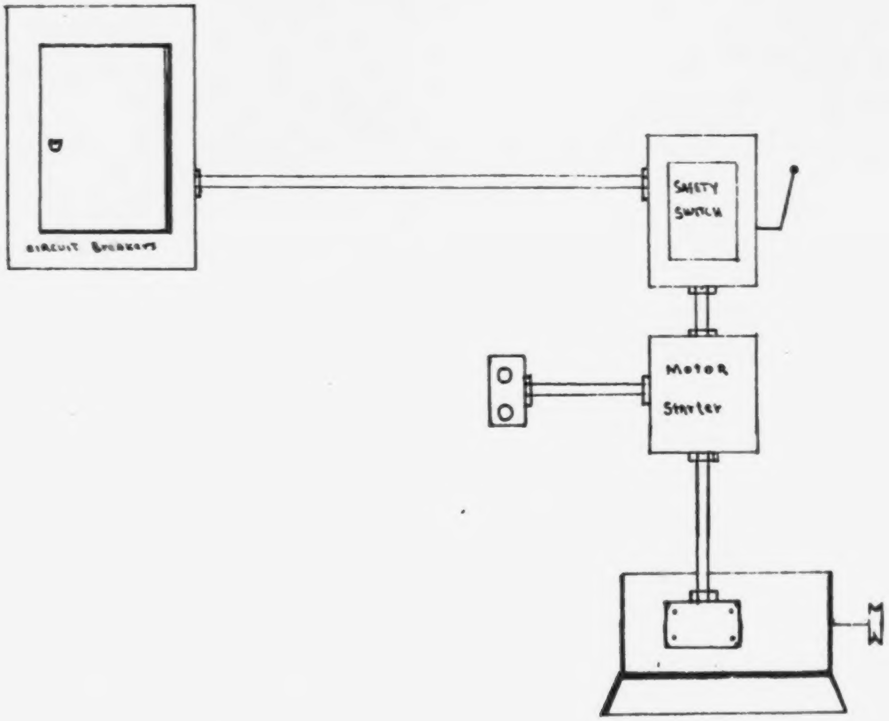


Figure 6-5. Motor Starter Circuit

## Motor Controllers and Controls

A motor controller is anything from a simple toggle switch to a complex system, which controls some operation of an electric motor.

Article 430 of the National Electric Code allows some motors in certain conditions to be controlled by a simple device, such as a toggle switch or safety switch, shown in figure 6-6.

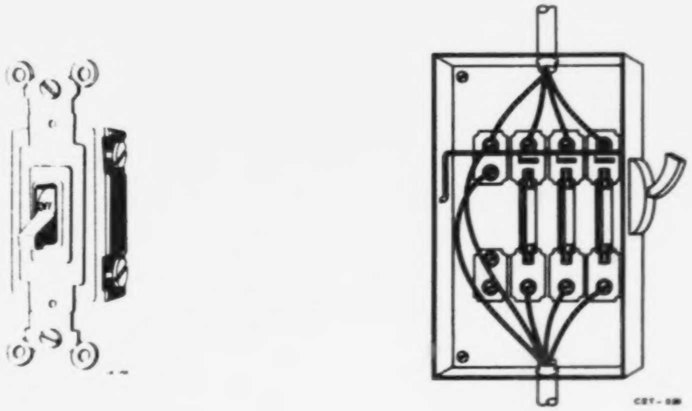


Figure 6-6. Toggle Switch and Safety Switch

Due to the size of a motor, the duty it is to perform, the location in which it is installed, or the construction of the motor, it may require additional protection and/or controlling devices.

## Types of Manual Controllers

TOGGLE SWITCH. When a toggle switch is used to control a motor, it normally controls a motor of low horsepower rating. An example of this would be a bathroom exhaust fan.

Where the supply voltage to the motor is 240 volts, you would have to use a double-pole toggle switch. This would allow you to break both hot conductors simultaneously.

SAFETY SWITCH. Safety switches of all designs will also be used as controllers in some cases. A non-fusible safety switch would provide only a manual control means, where a fusible safety switch can in some cases provide over-current protection and control means.

## Magnetic Line Voltage Starter

Electromagnetic energy can be used to close switches. Line voltage starters provide a safe, convenient and economic means for controlling electric motors. They are used to start and stop electric motors. Magnetic line starters are widely used because they are economical and [illegible] and they can also be controlled remotely. They are normally used where full voltage starting torque is needed and where current surge is not a major factor. Magnetic starters may be as simple as the type show in figure 6-7, having only one set of contacts. The contacts called "main contacts" would be connected in series with the conductor carrying power to the motor. When the electromagnetic coil is energized, it sets up a magnetic field attracting the armature. When the armature moves toward the electromagnet, the movable contact (located on the armature) connects with the stationary contact. This completes the circuit to the motor and the motor starts. When the switch in the circuit which supplies power for the electromagnetic coil is opened, the coil is de-energized, causing a loss of the magnetic force. The spring will then pull the contacts apart. This is a simple magnetic line starter. Other magnetic line starters will have more contacts, motor over-current protector relays (heaters), and may depend on gravity to open the contacts. Heaters will be explained later in this study guide. Figure 6-8 will help you identify the different parts of a magnetic across-the-line starter. This figure shows a three-phase across-the-line starter, containing three sets of main contacts, one set of holding contacts, a coil, two reset contacts, and two heaters. It is designed so gravity will cause the contacts to open when the coil is de-energized. Pressure springs have been added to the contacts to allow them to seat evenly. This prevents bending of the contacts and arcing, thus prolonging their life. Shaded rings are placed on the stationary core to provide a time delay in the loss of flux, thus preventing contact chatter and wear in the moving parts of AC magnetic starters.

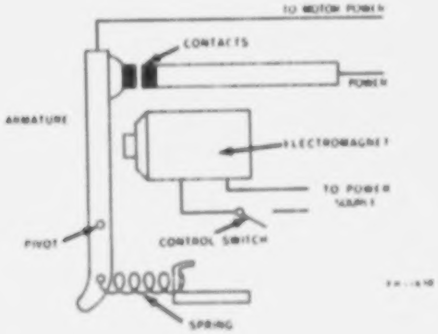

TO MOTOR POWER
CONTACTS
POWER
ARMATURE
ELECTROMAGNET
TO POWER SUPPLY
CONTROL SWITCH
PIVOT
SPRING

Figure 6-7. Magnetic Starter

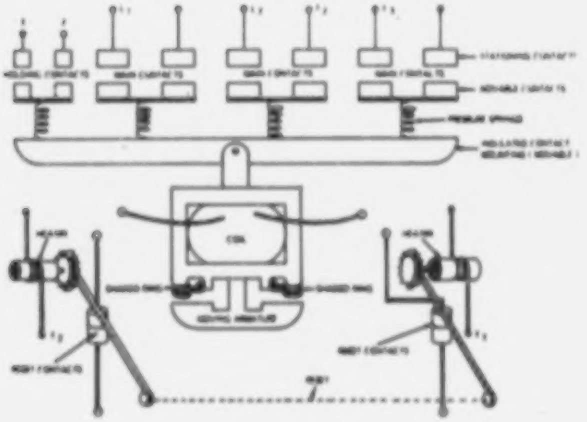

HOLDING CONTACTS
MAIN CONTACTS
STATIONARY CONTACT
MOVABLE CONTACTS
PRESSURE SPRING
COIL
HEATER
SHADED RING
MOVING ARMATURE
RESET CONTACTS
RESET

Figure 6-8. Three-Phase Magnetic Line Voltage Starter

Figure 6-9 shows how this starter will appear on an electrical diagram. Electrical symbols are used to represent the parts of the starter. Magnetic starters are often called contactors.

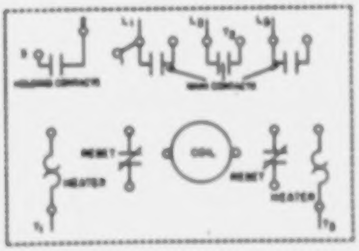


Figure 6-9. Electrical Diagram of a Magnetic Starter

### Overload Protection

Electric motors require overload protection to prevent burnout. If permitted, electric motors will operate at a higher current than their rated capacity. This may be caused by low line voltage, by an open line in a three-phase system, and by an overload of the driven machinery. The overload on an electric motor causes it to draw excessive current that causes overheating. The overheating will eventually result in a burnout. To prevent this, overload relays are employed on a starter to limit the amount of current a motor can draw. This is overload protection, or running protection. An overload relay consists of a current sensitive element and a set of normally closed reset contacts. The overload relays of a starter function to protect a motor from excessive current that is destructive to motors. Current sensitive (thermal or magnetic) elements of overload relays are connected either directly or indirectly in the motor lines through current transformers. The overload relays act to de-energize the starter and stop the motor when excessive current is drawn.

### Thermal Cutouts

Thermal cutouts are usually of the bimetallic or melting alloy types. The bimetallic type is constructed of two dissimilar metals which, when heated, bend due to the different rate of expansion of the two metals. A heating element in the motor line circuit generates the heat necessary to activate the strip. Current in excess of the desired amount causes deflection of the bimetallic strip to the extent that the contacts spring apart, thus opening the holding coil circuit as shown in figure 6-10. A reset button is depressed to reactivate the machanism when the strip has cooled to operating tolerance.

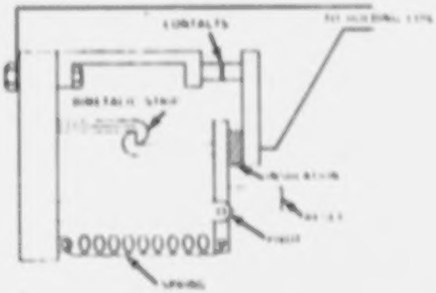


Figure 6-10. Bimetallic Overload Relay

The melting alloy overload relay employs a heating coil connected in the motor line circuit. See figure 6-11.

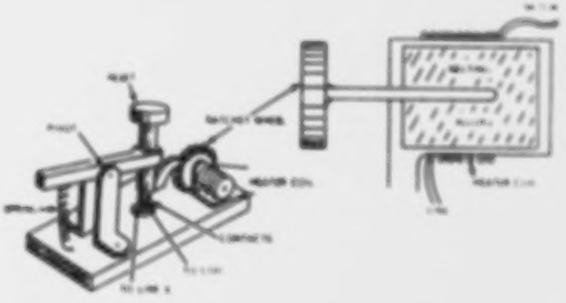


Figure 6-11. Melting Alloy Thermal Overload Relay

The heat caused by excessive current in the motor circuit melts the metal alloy (similar to solder) releasing the spring-loaded shaft. The shaft is then capable of turning which permits the reset contacts to open, thereby disrupting service to the motor. When the alloy has cooled and solidified sufficiently, the motor may be restarted by depressing the reset button. A laboratory example of the melting alloy principle is shown in the figure.

The main advantage of the melting alloy over the bimetallic type is its amperage rating doesn't vary after repeated heatings.

Magnetic Overloads

The magnetic overload relay consists of a coil, a plunger, a dashpot, and a set of contacts. See figure 6-12. The coil is connected in series with the motor. When a determined amount of current passes through the coil, the magnetic field will pull the plunger up causing the contacts to open. By adjusting the length of the plunger, the amount of current required to pull the plunger up can be varied. An oil-filled dashpot is added to provide a time delay. A plate on the bottom of the plunger is submerged in the oil and acts as a piston. The plate has holes in it that can be adjusted in size to change the time delay. When the coil pulls the plunger up, the oil must flow through the hole in the plate as the plunger rises. By changing the size of the hole, the time delay can be increased or decreased. Quick tripping is obtained through the use of a light grade dashpot oil.

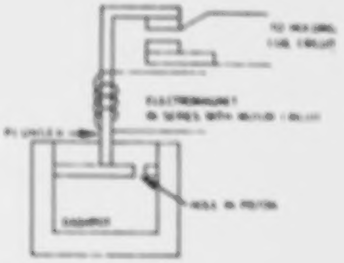


Figure 6-12. Magnetic Overload Relay

Selecting Heaters

The overload relay size is determined by the full load current of the motor it protects. When selecting the heaters to protect a motor, you should check the motor data plate to find the full load current. Each manufacturer normally puts a heater selection table in the controller cover. Heaters are not identified by amperage, but by the manufacturer's catalog number. By using the full load current of the motor to be protected and referring to the manufacturer's table, the proper heater can be selected. If the full load current of a 2 hp motor at 230V is 6.8 amps, the heater required would be a H1033, according to the Cutler-Hammer table.

## SELECTING EXTERNAL OVERLOAD DEVICES

This lesson is designed to teach you how to select the correct external overload device for a particular motor using tables provided by three different companies.

---

| WEE WILLIE MOTOR CO. | | | | |
|---|---|---|---|---|
| HP 2 | Ph 3 | | 50 HZ | 60 HZ |
| Volts 208/220/440 | | RPM - | 950 | 1145 |
| Frame 184 | Insul. Class B | Hi Volt Amps | 3.6 | 3.2 |
| Type K | | Low Volt Amps | 7.2 | 6.4 |
| Design B | NEMA CODE L | Rating Temp | 50°C | 40°C |
| Continuous Duty | Service Factor | | 1 | 1.25 |

**PROBLEM 1:**

Check the motor data plate shown above. If the motor is connected to low voltage, 60 Hz, what number overload would be used?

a. Square D. No. __________________

b. Allen Bradley No. __________________

c. Cutler-Hammer No. __________________

**PROBLEM 2:**

Check the motor data plate shown above. If the motor is connected to high voltage, 60 Hz, what number overload would be used?

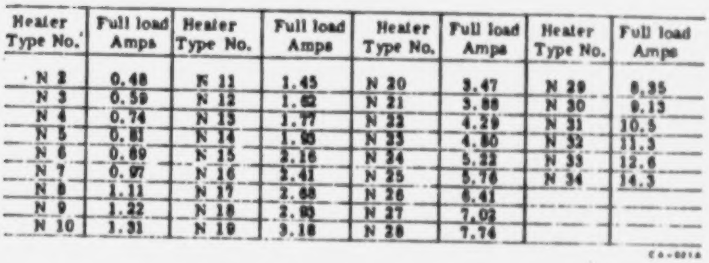
a. Square D. No. __________________

b. Allen Bradley No. __________________

c. Cutler-Hammer No. __________________

| Motor full load current | Relay Number | Motor full load current | Relay Number | Motor full load current | Relay Number | |
|---|---|---|---|---|---|---|
| [illegible] | B 0.44 | 1.97-2.23 | B 2.65 | 10.0-10.6 | B-14 | |
| [illegible] | B 0.51 | 2.24-2.50 | B 3.00 | 10.7-11.4 | B 15.5 | |
| [illegible] | B 0.57 | 2.51-2.81 | B 3.30 | 11.5-12.3 | B 17.5 | |
| [illegible] | B 0.63 | 2.82-3.19 | B 3.70 | 12.4-13.6 | B 19.5 | |
| [illegible] | B 0.71 | 3.20-3.61 | B 4.15 | 13.7-14.6 | B 22 | |
| [illegible] | B 0.81 | 3.62-4.14 | B 4.85 | 14.7-16.8 | B 25 | |
| [illegible] | B 0.92 | 4.15-4.40 | B 5.50 | 16.9-18.6 | B 28 | |
| [illegible] | B 1.03 | 4.41-4.78 | B 6.25 | 18.7-20.2 | B 32 | |
| [illegible] | B 1.16 | 4.79-5.44 | B 6.90 | 20.3-22.8 | B 36 | |
| [illegible] | B 1.30 | 5.45-6.16 | B 7.70 | 22.9-24.7 | B 40 | |
| [illegible] | B 1.45 | 6.17-6.86 | B 8.20 | 24.8-27.0 | B 45 | |
| [illegible] | B 1.67 | 6.87-7.64 | B 9.10 | | | |
| [illegible] | B 1.88 | 7.65-8.41 | B10.2 | | | |
| [illegible] | B 2.10 | 8.42-8.77 | B11.5 | | | |
| [illegible] | B 2.40 | 8.78-9.0 | B12.6 | | | |

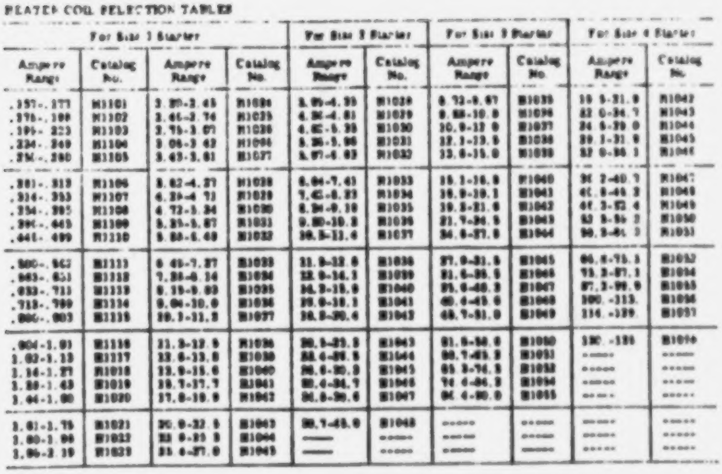
Square D Table



| Heater Type No. | Full load Amps | Heater Type No. | Full load Amps | Heater Type No. | Full load Amps | Heater Type No. | Full load Amps |
|---|---|---|---|---|---|---|---|
| N 2 | 0.48 | N 11 | 1.45 | N 20 | 3.47 | N 29 | 8.35 |
| N 3 | 0.59 | N 12 | 1.62 | N 21 | 3.88 | N 30 | 9.13 |
| N 4 | 0.74 | N 13 | 1.77 | N 22 | 4.29 | N 31 | 10.5 |
| N 5 | 0.81 | N 14 | 1.95 | N 23 | 4.80 | N 32 | 11.3 |
| N 6 | 0.89 | N 15 | 2.16 | N 24 | 5.22 | N 33 | 12.6 |
| N 7 | 0.97 | N 16 | 2.41 | N 25 | 5.76 | N 34 | 14.3 |
| N 8 | 1.11 | N 17 | 2.68 | N 26 | 6.41 | | |
| N 9 | 1.22 | N 18 | 2.93 | N 27 | 7.02 | | |
| N 10 | 1.31 | N 19 | 3.18 | N 28 | 7.74 | | |

CA-0016

Allen Bradley Table



HEATER COIL SELECTION TABLES

Cutler-Hammer Heater Table

Solution 1

a. B 8.20

b. N 26

c. H 1032

Solution 2

a. B 4.15

b. N 19

c. H 1066

# MOTOR SAFETY

## Turn the power OFF before doing any type of work involving electric motors

Many people have been killed or injured with electricity because they THOUGHT the power was off. It is standard practice to check all "hot" wires with a voltmeter to make sure that the power is off. Some motors have start capacitors that remain energized even if the power is turned off. If a motor has a start capacitor, it should be discharged with a bleed resistor. (Bleed resistor: 2 Watt, 15,000 Ohms) A bleed resistor will slowly "bleed" the power stored in the capacitor. Use an insulated tool to hold the resistor across the capacitor terminals for about ten seconds. Don't use a screwdriver to discharge capacitors! A screwdriver will discharge the capacitor too quickly and could cause it to explode. The fluid inside of most capacitors is toxic.... avoid handling it or breathing the fumes.

## Avoid coming in contact with moving parts of a motor

People have been killed or injured by getting their hair, fingers, or clothes caught in motors. Keep all protective guards and covers in place and be cautious of ANY moving equipment.

## Motors must be kept clean

A dirty motor can cause a fire. Proper lubricating and housekeeping practices are very important. Oil, grease, dust and lint can catch on fire.

## Do not remove or destroy data plates

The data plate provides important information about a motor that can help a qualified technician keep it operating safely.

## Motors must be properly wired

Motor connection diagrams are available for all electric motors. One wire out of place can destroy a motor and cause sparks to fly!

## The metal frame of motors and all related equipment must be grounded

An ohmmeter will indicate continuity if connected to a properly grounded motor and any related equipment that is grounded. Continuity must exist between a motor, motor starter, fused safety switch, breaker panel and any object that actually goes into the ground.

# MOTOR PROBLEMS AND CAUSES

## FAILURE TO START:

1. Blown fuse, tripped circuit breaker, open overload device
2. Low voltage or no voltage
3. Undersized wires
4. Improperly wired
5. Poor wire connections
6. Undersized motor
7. Defective capacitor
8. Locked rotor (stuck)
9. Damaged motor windings

## EXCESSIVE NOISE:

1. Improperly mounted
2. Improperly aligned
3. Loose parts
4. Bent shaft
5. Damaged or excessively worn bearings
6. Dirty motor

## OVERHEATING OF BEARINGS

1. Lack of lubrication
2. Improper lubrication
3. Damaged or excessively worn bearings
4. Excessive belt tension
5. Bent shaft

## OVERHEATING OF MOTOR:

1. Undersized motor
2. Undersized wire
3. Poor wire connections
4. Incorrect voltage
5. High room temperature
6. Dirty motor
7. Poor air circulation
8. Defective capacitor
9. Damaged motor windings

# ELECTRIC MOTOR REMOVAL AND REPLACEMENT PROCEDURES

If a decision to remove and replace a motor has been made, the following procedures should be followed as a basic guideline.

## REMOVAL PROCEDURES

1. Turn the power off.....Inspect the defective motor and attempt to identify the cause of failure.
2. Copy the information on the data plate.....This information is necessary to find a suitable replacement.
3. Identify wiring connections.....Make a drawing of the wire connections and/or tag each wire with numbered wire markers.
4. Determine the direction of rotation.....Examine the driven equipment (pump, fan, etc.) to determine the direction of rotation.
5. Study the mounting, alignment and position of the motor.....Eliminate confusion during the installation of replacement motor.
6. Remove the defective motor.....Take precautions to avoid losing parts (nuts, bolts, washers, pulleys, belts, etc.)

## REPLACEMENT PROCEDURES

1. Select a suitable replacement.....Use the information from the original motor data plate. Attempt to find an exact replacement as this will make installation easy. Exact replacements are not always available and a substitute replacement may have to be used.
2. Install the replacement motor.....

   Exact replacement: If the replacement motor is identical to the original, simply put it in the way the original one was.

   Substituted replacement: If the replacement motor is not identical to the original, make sure there are adequate installation instructions.

# ROTATION PROCEDURES

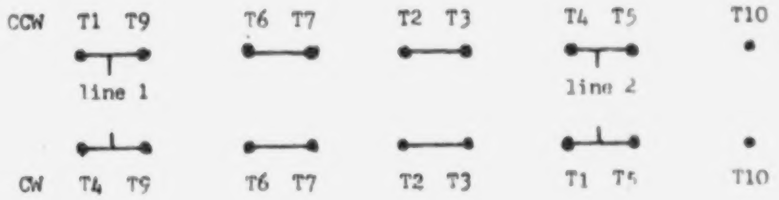
During the installation of some replacement motors, it may be necessary to change the direction of rotation to suit the particular need of the driven equipment (pump, fan, etc.).

## Single-Phase Motors

The rotation of some single-phase motors can be reversed by the technician. Single-phase motors that have the capability of being reversed may be either "electrically reversible" or "mechanically reversible." Always follow the manufacturers instructions when changing rotation.

- "ELECTRICALLY REVERSIBLE"...Interchange the start winding leads. This type of motor has accessible start winding leads.

  EXAMPLE: (Taken from the data plate of a particular single-phase motor designed to operate at 230 VAC.)

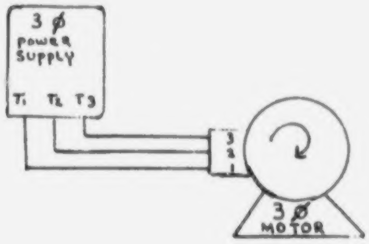

CCW
T1 T9
line 1
T6 T7
T2 T3
T4 T5
line 2
T10
CW
T4 T9
T6 T7
T2 T3
T1 T5
T10

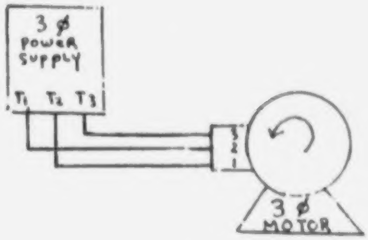
- "MECHANICALLY REVERSIBLE"...Disassemble the motor and turn the rotor around. This type of motor can be recognized by notches cut into each of the stator poles.

---

## Three-Phase Motors

All three-phase motors are electrically reversible. Interchange any two of the three power leads.


3 ϕ
power
supply
T1 T2 T3
3
2
1
3 ϕ
MOTOR


3 ϕ
power
supply
T1 T2 T3
3
2
1
3 ϕ
MOTOR

## ELECTRICAL MOTOR INSPECTION AND MAINTENANCE PROCEDURES

Electric motors must be periodically inspected and maintained to insure proper operation. Inspection and maintenance checklists are often used to provide guidelines to follow. A sample checklist is shown below:

### INSPECTION AND MAINTENANCE CHECKLIST

(Steps 1 through 6 are done with the power OFF)

1. CLEANLINESS...Remove dirt, dust and lint from the motor with clean rags or compressed air.
2. ELECTRICAL CONNECTIONS...All electrical connections must be mechanically and electrically secure.
3. NOISE/VIBRATION...Inspect for loose parts, proper mounting, alignment, etc.
4. LUBRICATION...Check shaft for ease of rotation. Shaft should turn smoothly. If lubrication is required, get specific lubrication instructions for each different motor. Some motors require oil while others require grease.
5. BEARINGS...Inspect for damaged or excessively worn bearings by turning shaft and listening for unusual sounds.
6. END-PLAY/SIDE-PLAY...Inspect shaft of motor to determine if there is excessive movement from end-to-end or side-to-side.

(Steps 7 through 10 are done with the power ON)

7. RPM...Listen and look at the motor to determine if it is operating at the proper speed. (Good judgement is required) Special instruments can be used to measure RPM.
8. AMPERAGE...Use an ammeter to check the amperage. Amperage should be at or below the amperage rating listed on the data plate.
9. VOLTAGE...Use a voltmeter to check voltage. The voltage applied to a motor should be within 10% of the voltage rating listed on the data plate.
10. TEMPERATURE...Use a thermometer to check temperature. The measured temperature should be less than the allowable temperature as determined by the insulation class. Class A...90°C Class B...110°C Class H...150°C.

## SUMMARY

The material in this unit was presented under the following main topics:

- BASIC CONSTRUCTION FEATURES OF ELECTRIC MOTORS
- THEORY OF OPERATION OF ELECTRIC MOTORS
- INTRODUCTION TO ELECTRIC MOTORS (TERMINOLOGY)
- MOTOR OVERLOAD PROTECTION
- MOTOR STARTERS
- MOTOR STARTERS WITH OVERLOAD PROTECTION
- SELECTING EXTERNAL OVERLOAD DEVICES
- MOTOR SAFETY
- MOTOR PROBLEMS AND CAUSES
- ELECTRIC MOTOR REMOVAL AND REPLACEMENT PROCEDURES
- ROTATION REVERSAL PROCEDURES
- ELECTRIC MOTOR INSPECTION AND MAINTENANCE PROCEDURES

## NOTES

257

WORKBOOKS

J3ABR54532 001-II-1 thru II-6

Technical Training

# Heating Systems Specialist

# BASIC ELECTRICITY

October 1984

3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

DESIGNED FOR ATC COURSE USE

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This publication supersedes WB J3ABR54532 001-III-1 thru II-6 dated February 1983. Copies of superseded publication can be used until supply is exhausted.

# ELECTRICAL FUNDAMENTALS

## OBJECTIVES

Given information, identify basic facts relating to electrical fundamentals by correctly answering 70% of the questions.

Given fuses, fuse puller and fused safety switch, install circuit protective devices with a maximum of two instructor assists.

## PROCEDURE

Complete exercises as directed by instructions listed for each exercise.

## EXERCISE 1
## ELECTRICAL SAFETY PRACTICES

INSTRUCTION:

In the spaces below, list 10 electrical safety practices to be used when working with electrical equipment.

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

## EXERCISE 2
## INSTALLATION OF CIRCUIT PROTECTIVE DEVICES
## PROGRESS CHECK 1b

INSTRUCTION:

You will be graded on your ability to remove and install fuses in a fused safety switch. Your instructor will demonstrate safe electrical practices that are used in the performance of this task.

CAUTION: Remove jewelry, wear appropriate eyewear (metal rims or frames are not permitted). Obtain approved fuse puller from instructor. Work carefully and ask questions if you are not sure what to do.

INSTALL CIRCUIT PROTECTIVE DEVICES

1. De-energize fused safety switch by moving the switch handle to the OFF position. (CAUTION: A portion of the safety switch will still be "hot" even with the switch in the off position.)

2. Perform a visual inspection of the safety switch:

   a. Construction features

   b. Maximum amperage rating of switch

   c. Type and amperage rating of fuses

   d. Electrical connections

   e. Cleanliness

3. Grasp each fuse with fuse puller and remove them from the fuse holders.

4. Select replacement fuses.

5. Install each replacement fuse into the fuse holders. A distinctive "snap" will be heard and felt to indicate that the fuse is secure.

## EXERCISE 3
## ELECTRICAL FUNDAMENTALS

INSTRUCTIONS:

Fill in the blanks as directed by your instructor.

1. The smallest part of an element is the __________________________.

2. An atom is made up of ________________, _________________, and __________________.

3. An electron has a _____________________ electrical charge.

4. Under normal conditions, atoms are ____________________________.

5. Atoms that have become unbalanced are _________________________.

6. An atom that has gained electrons is considered to be _________________________.

7. The Electron Theory states that electrical current will flow from a _______________ charge to a _______________________ charge.

8. _________________________ is the electrical energy or electron moving force produced by negative and positive electrical charges.

9. A _________________________ converts heat energy into electrical energy.

10. A _________________________ converts chemical energy into electrical energy.

11. A ________________________ converts mechanical energy into electrical energy.

12. The amount of current flow through a wire is measured in ____________________.

13. ____________________ current travels in only one direction.

14. 120 VAC, 60 Hertz refers to ________________________ current.

15. An insulator has ___________________ resistance.

16. A conductor has ____________________ resistance.

17. Electricity can travel easier through a _____________ wire.

18. The maximum allowable current flow through a No. 14 solid wire is ___________ amps.

19. A green colored wire represents a ________________ wire.

20. A switch in the open position is __________________.

21. Fuses are rated by ___________________________.

22. A circuit breaker "trips" because of too much __________________.

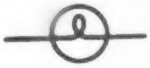
23. A circuit with low resistance will have ______________ current flow.

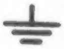
## EXERCISE 4
## ELECTRICAL SYMBOLS

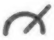
INSTRUCTION:

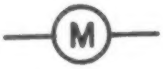
Match the symbol by letter to name that identifies it.

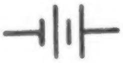
1. ____________ ohmmeter
2. ____________ circuit breaker
3. ____________ fuse
4. ____________ SPST switch
5. ____________ ammeter
6. ____________ AC motor
7. ____________ transformer
8. ____________ temperature switch
9. ____________ normally open contacts
10. ____________ AC generator
11. ____________ battery
12 ____________ thermocouple/thermopile
13. ____________ lamp
14. ____________ ground
15. ____________ coil
16. ____________ normally closed contacts
17. ____________ voltmeter
18. ____________ pressure switch
19. ____________ capacitor
20. ____________ electrode

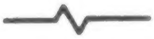
(a) 

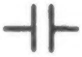
(b) 

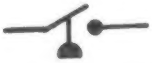
(c) 

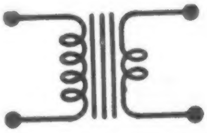
(d) 

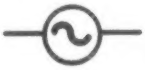
(e) 

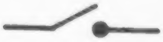
(f) 

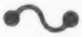
(g) 

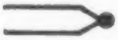
(h) 

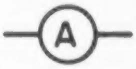
(i) 

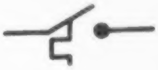
(j) 

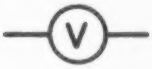
(k) 

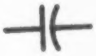
(l) 

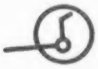
(m) 

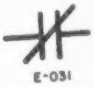
(n) 

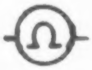
(o) 

(p) 

(q) 

(r) 

(s) 

(t) 

# THEORY OF MAGNETISM AND TRANSFORMERS

## OBJECTIVE

Given information, identify basic facts relating to the theory of magnetism and transformers by correctly answering 70% of the questions.

## PROCEDURE

## EXERCISE 1
## THEORY OF MAGNETISM AND TRANSFORMERS

INSTRUCTION:

You will be graded on your ability to identify basic facts relating to the theory of magnetism and transformers.

1. Any material attracted by a ____________________ is a magnetic material.
2. The ability of an object to attract iron or steel is known as ____________________.
3. The invisible magnetic force surrounding a magnet is known as the ________________.
4. Unlike poles of a magnet ______________________.
5. A _____________________ material is believed to consist of millions of tiny magnets.
6. Some materials become magnetized when in a magnetic field. If the material is no longer magnetized when the magnet is taken away, the materials are considered to be ____________________ magnets.
7. Magnetism produced by electricity is known as _____________________.
8. When electric current flows through a (an) _____________________, a magnetic field is produced.
9. An electromagnetic device becomes a magnet when _____________________.
10. When the current flow through an electromagnet stops, it will ____________ its magnetism.
11. An electrical device that is designed to control the flow of water, oil or gas is known as a ________________ valve.
12. A control relay is an electrically operated ____________________.
13. The moving part of a relay is known as a (an) ______________________.
14. A relay that has contacts in the open position when the relay coil is not energized is considered to be normally ________________.
15. A device that changes alternating current from one voltage to another is a ________ ________________.
16. The ______________ coil of a transformer is connected to the power source.
17. The ___________________ coil of a transformer is connected to the load device.
18. A transformer that has a higher number of turns of wire in the secondary coil is
19. considered to be a ____________________ transformer.

A low-voltage control transformer steps voltage ________.

20. A high-voltage ignition transformer steps voltage ______.

# TYPES AND CHARACTERISTICS OF ELECTRICAL CIRCUITS

## OBJECTIVES

Given information, identify basic facts relating to types and characteristics of electrical circuits, by correctly answering 70% of the questions.

Using electrical circuit trainer, construct electrical circuits with a maximum of two instructor assists.

## PROCEDURE

Complete exercises as directed by instructions listed for each exercise.

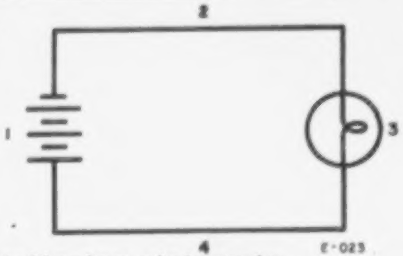
## EXERCISE 1
## ELECTRICAL CIRCUITS

## INSTRUCTION

You will be graded on your ability to identify basic facts relating to electrical circuits and the application of Ohm's Law.

1. A circuit is defined as having a complete path for ____________ flow.

2. Identify the basic parts of the circuit drawn below



   a. ________= NEGATIVE CONDUCTOR
   b. ________= POSITIVE CONDUCTOR
   c. ________= POWER SOURCE
   d. ________= LOAD DEVICE

3. Label the type of circuit that is described in the following statements.

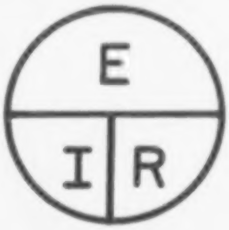
   a. ____________ Current has only one path it can take and has one load device.
   b. ____________ Current has only one path it can take and has two or more load devices.
   c. ____________ Current has more than one path it can take and has one load device in each path.
   d. ____________ A combination of both series and parallel components.

4. Complete the following statements:

   a. The mathematical relationship between voltage, current and resistance of a circuit is known as ____________________.
   b. The two electrical factors that must be known to calculate voltage are ____________________.
   c. The two electrical factors that must be known to calculate current are ____________________.
   d. The two electrical factors that must be known to calculate resistance are ____________________.

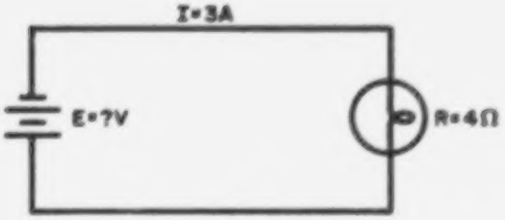
5. Complete the following Ohm's Law equations:

   a. E = ____X____
   b. I = ____÷____
   c. R = ____÷____



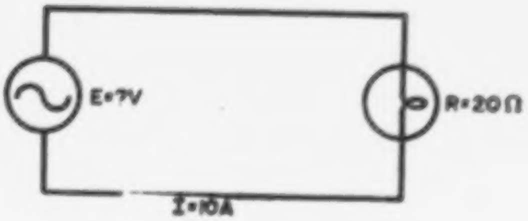
8. Use Ohm's law to solve the following problems:

(a)



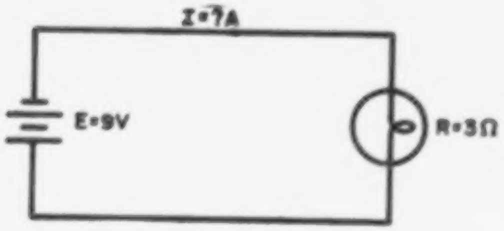
E = ________________ volts

(b)


E=?V
R=20Ω
I=10A

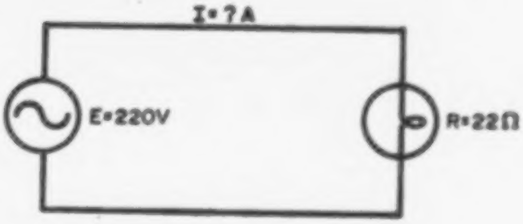
E = ________________ volts

(c)



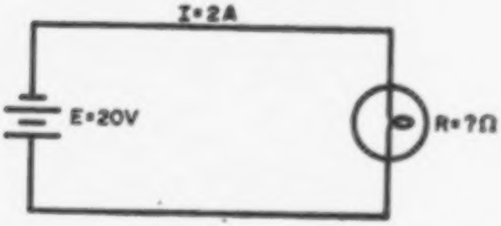
I = ________________ amperes

(d)


I=?A
E=220V
R=22Ω

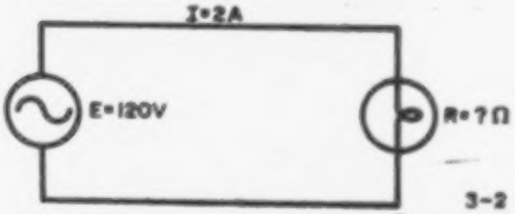
I = ________________ amperes

(e)



R = ________________ Ohms

(f)


I=2A
E=120V
R=?Ω

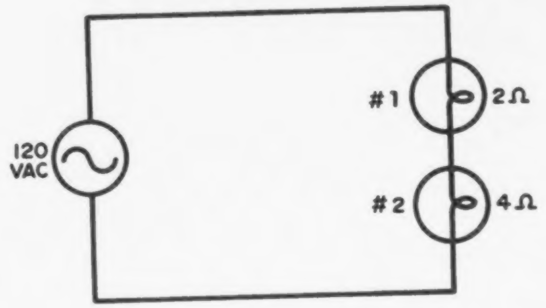
R = ________________ Ohms

7. Characteristics of series load circuits:

1 The sum of the voltage measured across each load device will equal the total applied voltage.

2 The same amount of current will flow throughout the circuit.

3 The sum of the resistances of each load device will equal the total resistance.



a. The voltage consumed by lamp 1 is ____________ volts.

b. The voltage consumed by lamp 2 is ____________ volts.

c. Total applied voltage to this circuit is ______________ volts.

d. The amount of current flow through lamp 1 is ____________ amps.

e. The amount of current flow through lamp 2 is ____________ amps.

f. Total current flow through the entire circuit is _____________ amps.

g. The resistance of lamp 1 is ________ ohms.

h. The resistance of lamp 2 is ________ ohms.

i. The combined resistance of this circuit is __________ ohms.

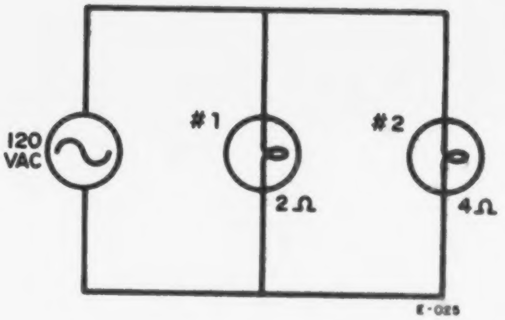
| | | | |
|---|---|---|---|
| F | | | |
| I | | | |
| R | | | |
| | Lamp 1 | Lamp 2 | TOTAL |

8. Characteristics of parallel load circuits:

1 Each load device will receive the same amount of voltage.

2 The total amount of current in the circuit represents the sum of the current flow through each path.

3 The total resistance of the circuit is always less than any individual resistance.



a. The voltage consumed by lamp 1 is ______ volts.

b. The voltage consumed by lamp 2 is ______ volts.

c. Total applied voltage to this circuit is ______ volts.

d. The amount of current flow through lamp 1 is ______ amps.

e. The amount of current flow through lamp 2 is ______ amps.

f. Total current flow through the entire circuit is ______ amps.

g. The resistance of lamp 1 is ______ ohms.

h. The resistance of lamp 2 is ______ ohms.

i. The combined resistance of this circuit is ______ ohms.

|  | Lamp 1 | Lamp 2 | TOTAL |
|---|---|---|---|
| E |  |  |  |
| I |  |  |  |
| R |  |  |  |

# EXERCISE 2
# CONSTRUCTING ELECTRICAL CIRCUITS

## PROGRESS CHECK 3b

*INSTRUCTION*

You will be graded on your ability to construct electrical circuits. This progress check is divided into four sections representing simple, series, parallel and series-parallel circuits. Your instructor will be closely monitoring your work to determine if you fail to demonstrate the appropriate level of proficiency.

CAUTION: Remove jewelry, wear appropriate eyewear; metal rims or frames are not permitted. Obtain wiring from trainer drawer and carefully inspect them for safety. If additional wires are needed, ask instructor. (Do not take wires from other trainers) Work safely and ask questions if you are not sure about what to do.

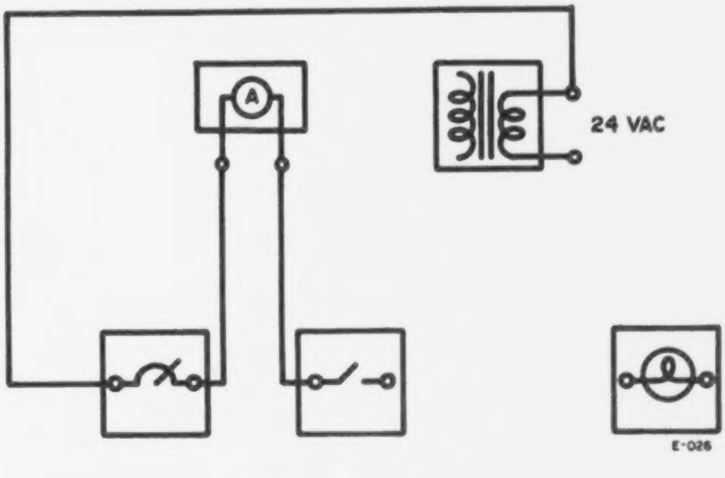
CONSTRUCT A SIMPLE CIRCUIT

STEP 1: Complete the drawing to represent a simple circuit.

STEP 2: Wire the circuit on the trainer using your drawings as a guide.

STOP HAVE THE INSTRUCTOR CHECK YOUR CIRCUIT

STEP 3: Apply power to your circuit and check for proper operation.



Simple Circuit

270

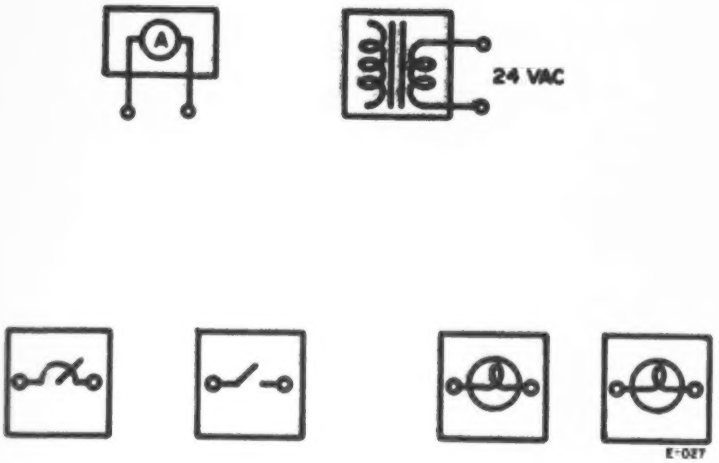
# CONSTRUCT A SERIES CIRCUIT

STEP 1: Complete the drawing to represent a series circuit.

STEP 2: Wire the circuit on the trainer using your drawing as a guide.

**STOP** HAVE THE INSTRUCTOR CHECK YOUR CIRCUIT

STEP 3: Apply power to your circuit and check for proper operation.



Series Circuit

## CONSTRUCT A PARALLEL CIRCUIT

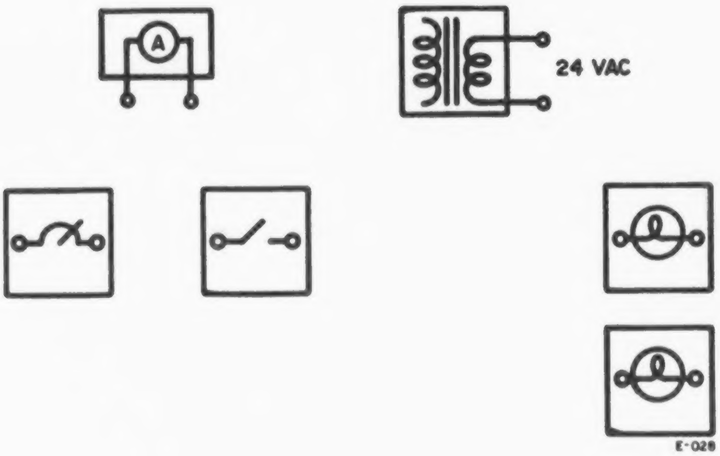
STEP 1: Complete the drawing to represent a parallel circuit.

STEP 2: Wire the circuit on the trainer using your drawing as a guide.

STOP

HAVE THE INSTRUCTOR CHECK YOUR CIRCUIT

STEP 3: Apply power to your circuit and check for proper operation.



Parallel Circuit

## CONSTRUCT A SERIES-PARALLEL CIRCUIT

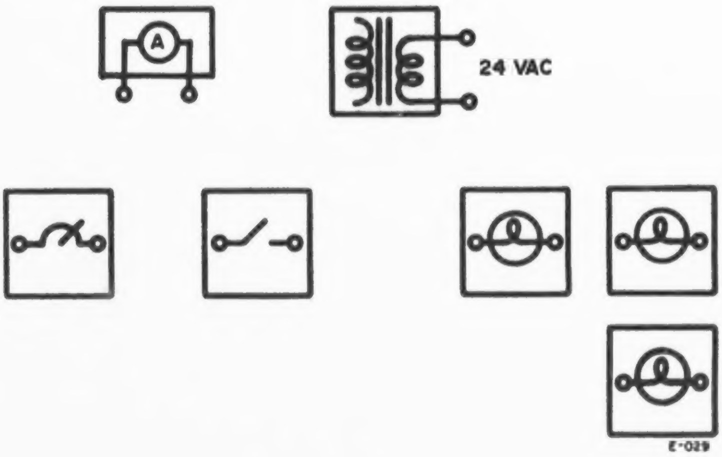
STEP 1: Complete the drawing to represent a series-parallel circuit.

STEP 2: Wire the circuit on the trainer using your drawing as a guide.

STOP

HAVE THE INSTRUCTOR CHECK YOUR CIRCUIT

STEP 3: Apply power to your circuit and check for proper operation.



Series-Parallel Circuit

## ELECTRICAL WIRING DIAGRAMS

### OBJECTIVE

Using the electrical diagrams, trace electrical circuits to determine operating characteristics, by answering correctly 70% of the questions.

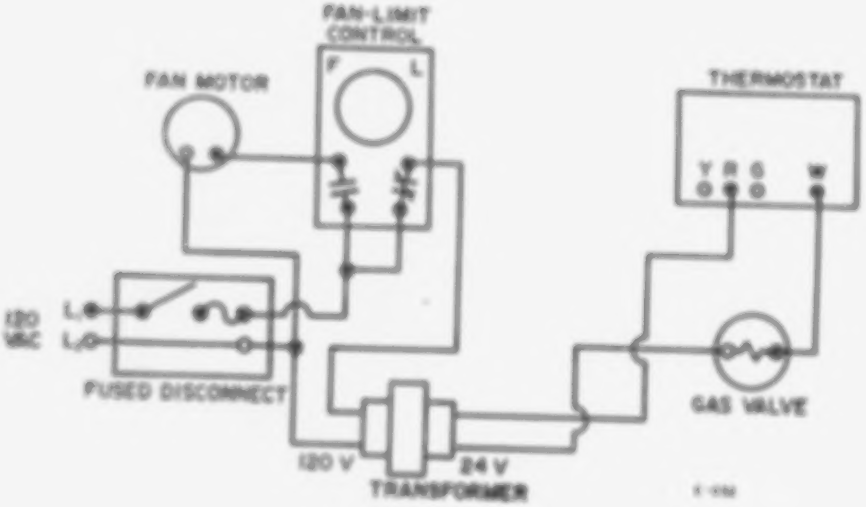
### PROCEDURES

Complete exercise as directed by your instructor.

## EXERCISE 1
## ELECTRICAL WIRING DIAGRAMS

INSTRUCTION:

You will be graded on your ability to provide information relating to electrical circuits. Correctly identify a minimum of 70% of the responses. Write the word TRUE or FALSE as it applies to each statement.


FAN-LIMIT CONTROL
F
L
FAN MOTOR
THERMOSTAT
Y R G W
120 VAC
$L_1$
$L_2$
FUSED DISCONNECT
GAS VALVE
120 V
24 V
TRANSFORMER

DOMESTIC FURNACE DIAGRAM

(1-5) Use figure to determine if the statements below are True or False.

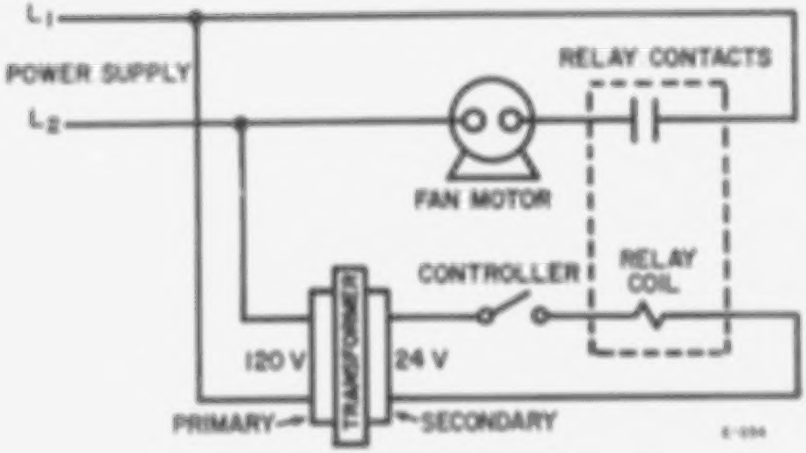
1. ___________120 volts are applied to $L_1$ and $L_2$.

2. ___________The fan motor receives 24 volts during operation.

3. __________The gas valve receives 240 volts during operation.

4. __________Terminals R and W must be connected to energize the gas valve.

5. __________The limit control contacts are shown to be closed.


L1
POWER SUPPLY
L2
RELAY CONTACTS
FAN MOTOR
CONTROLLER
RELAY COIL
120 V
TRANSFORMER
24 V
PRIMARY
SECONDARY

Fan relay circuit

(6-11) Use figure to determine if the statements below are True or False.

6. ____________ The transformer receives 120 volts from the power supply.

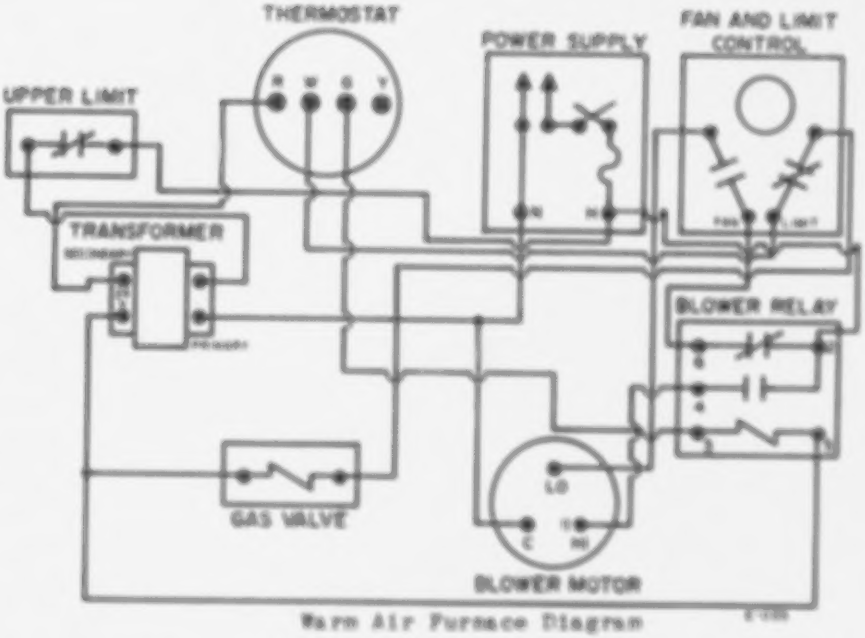
7. ____________ The power supply is connected to the secondary side of the transformer.

8. ____________ The relay coil will receive 24 volts when the controller switch is closed.

9. ____________ The fan motor will receive 24 volts when the relay coil is energized.

10. ____________ The fan motor will operate continuously.

11. ____________ The relay contacts are normally open.


THERMOSTAT
R W G Y
UPPER LIMIT
POWER SUPPLY
N
H
FAN AND LIMIT CONTROL
FAN
LIMIT
TRANSFORMER
SECONDARY
PRIMARY
BLOWER RELAY
GAS VALVE
LO
C
HI
BLOWER MOTOR

Warm Air Furnace Diagram

(12-20) Use Figure to determine if the statements below are True or False.

12. __________ Blower relay contacts 2 and 6 are normally closed.

13. __________ Terminal R of the transformer is connected to terminal R on the thermostat.

14. __________ The blower motor can operate at 2 different speeds.

15. __________ The limit and the upper limit contacts are normally open.

16. __________ Terminals 2 and 3 of the blower relay are normally closed.

17. __________ If the thermostat terminals R and W make contact, the gas valve would become energized.

18. __________ If the thermostat terminals R and G make contact, the blower motor would become energized.

19. __________ Thermostat terminals R and G are connected to 120 volts.

20. __________ If thermostat terminals R and Y make contact, the transformer would become energized.

# ELECTRICAL TEST EQUIPMENT

## OBJECTIVES

Using multimeter, select, care and use Ohmmeter function(continuity) by correctly identifying the resistance characteristics of 70% of the devices.

Using multimeter, select, care and use voltmeter function by correctly identifying the voltage characteristics of 70% of the electrical devices.

Using multimeter, select care and use Ommeter function by correctly identifying amperage characteristics of 3 out of 4 electrical devices.

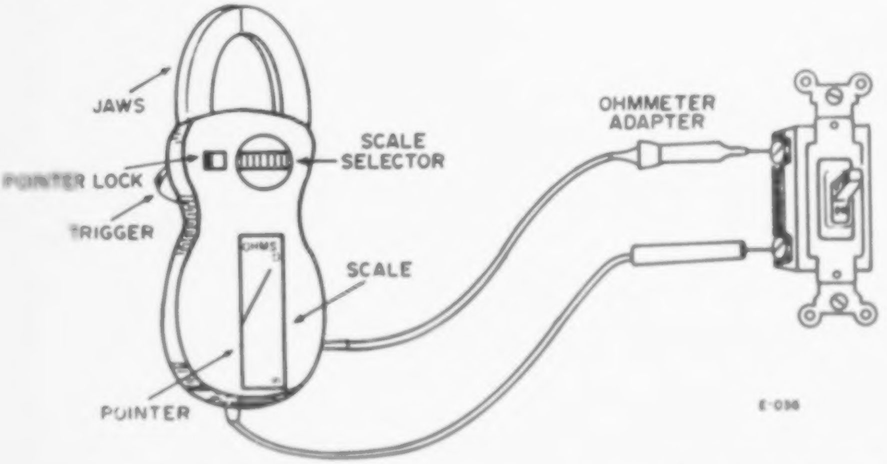
## PROCEDURE

Complete exercises as directed by instructions given for each exercise.

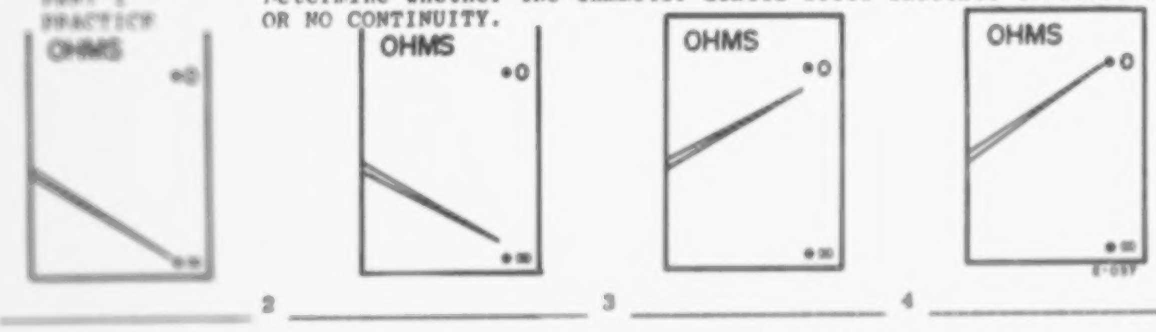
## EXERCISE 1
## ELECTRICAL TEST EQUIPMENT---OHMMETER
## PROGRESS CHECK 5a

INSTRUCTION:

You will be graded on your ability to select, care and use an ohmmeter by checking continuity of 10 electrical items. (fuses, switches, wires, etc.) A minimum of 7 correct responses is required.



**PART 1 PRACTICE** Determine whether the ohmmeter scales below indicate CONTINUITY OR NO CONTINUITY.



1 ____________ 2 ____________ 3 ____________ 4 ____________

(Never use the ohmmeter to check anything that has power applied to it.)

**PART 2 GRADED** Write CONTINUITY or NO CONTINUITY in the blank that describes each item you check.

1 ____________ 2 ____________ 3 ____________ 4 ____________

5 ____________ 6 ____________ 7 ____________ 8 ____________

9 ____________ 10 ____________

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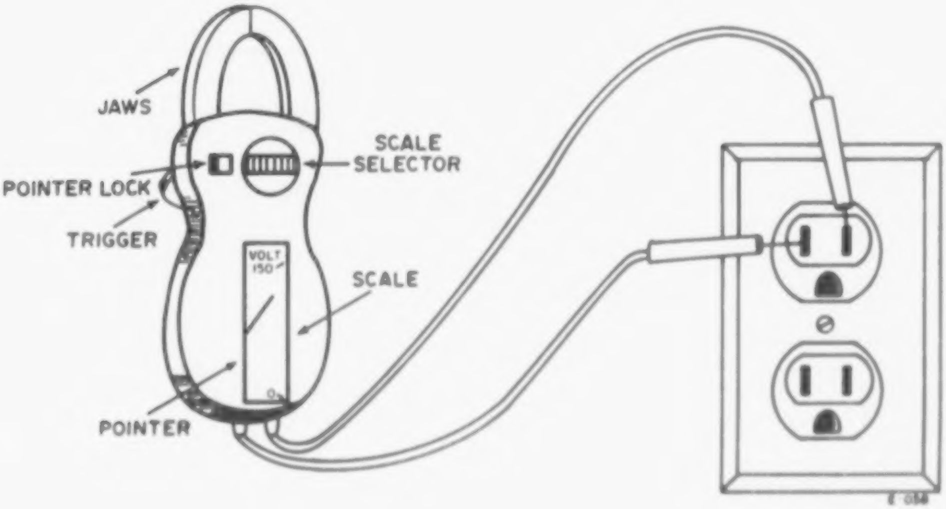
## EXERCISE 2
## ELECTRICAL TEST EQUIPMENT -- VOLTMETER

PROGRESS 5B

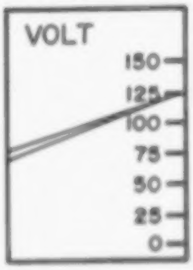
INSTRUCTION:

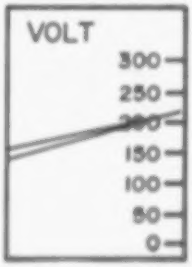
You will be graded on your ability to select, care and use a voltmeter by measuring voltage at 10 different test stations. A minimum of 7 correct responses is required.

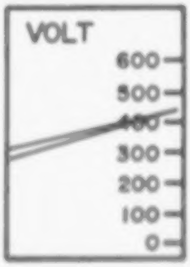

JAWS
SCALE SELECTOR
POINTER LOCK
TRIGGER
VOLT 150
SCALE
POINTER

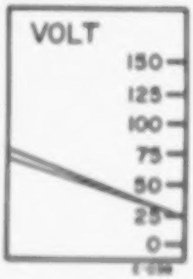
---

**PART 1 PRACTICE** Determine the voltage indicated on the scales below.


VOLT
150
125
100
75
50
25
0


VOLT
300
250
200
150
100
50
0


VOLT
600
500
400
300
200
100
0


VOLT
150
125
100
75
50
25
0

1 ____________ 2 ____________ 3 ____________ 4 ____________

(Always set the voltmeter on its highest range when measuring an unknown voltage.)

---

**PART 2 GRADED** Record voltage readings from each test station in the blanks below.

1 ____________ 2 ____________ 3 ____________ 4 ____________

5 ____________ 6 ____________ 7 ____________ 8 ____________

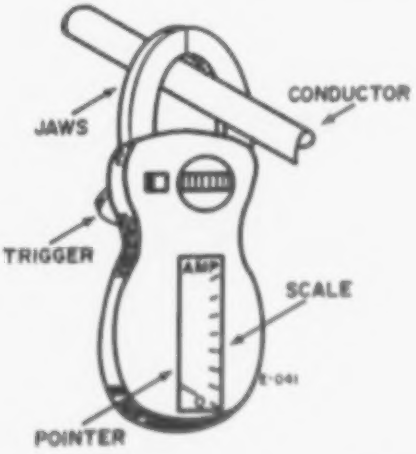
9 ____________ 10 ____________

EXERCISE 3
ELECTRICAL TEST EQUIPMENT---AMMETER

PROGRESS CHECK 5c

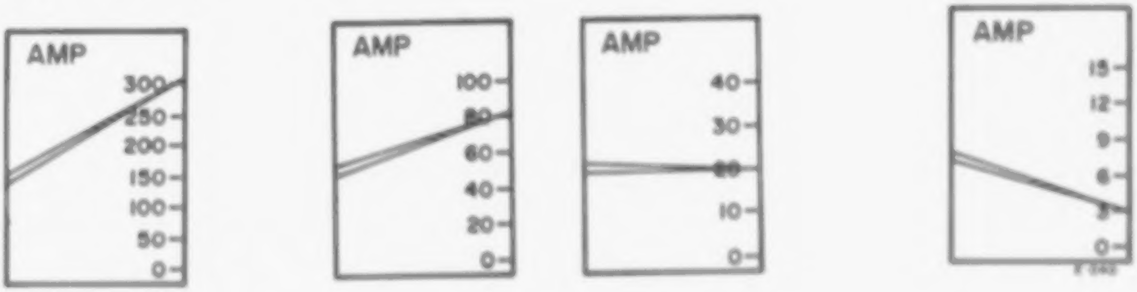
INSTRUCTION:

You will be graded on your ability to select, care and use an ammeter by checking amperage at 4 different amperage test stations. A minimum of 3 correct responses is required.


JAWS
CONDUCTOR
TRIGGER
AMP
SCALE
POINTER
2-041

---

PART 1
PRACTICE


AMP
300
250
200
150
100
50
0
AMP
100
80
60
40
20
0
AMP
40
30
20
10
0
AMP
15
12
9
6
3
0
2-042

1 ________ AMPS 2 ________ AMPS 3 ________ AMPS 4 ________ AMPS

(Always set the ammeter on its highest range when measuring unknown amperage. Clamp the ammeter around one current carrying conductor. Placing the ammeter around two current carrying conductors will given an inaccurate reading.)

---

PART 2 RECORD AMPERAGE READINGS FROM EACH TEST STATION IN THE BLANKS BELOW
GRADED

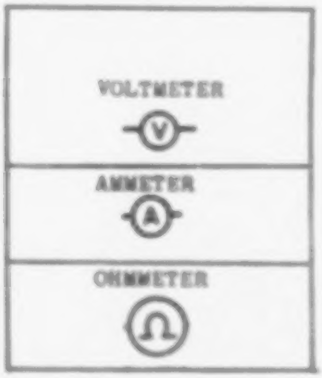
1 ________ 2 ________ 3 ________ 4 ________

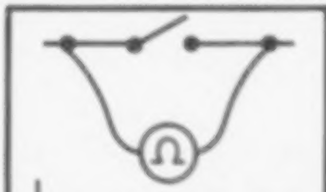
## EXERCISE 4
## USE OF ELECTRICAL TEST EQUIPMENT IN ELECTRICAL CIRCUITS

INSTRUCTION:

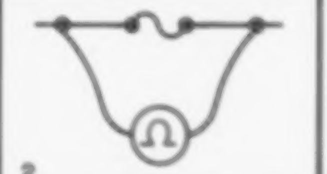
Select the response indicated by the electrical test equipment used in the drawings.

a. ZERO AMPS
b. ZERO VOLTS
c. INFINITY (NO CONTINUITY)
d. CONTINUITY
e. APPLIED VOLTAGE
f. CURRENT

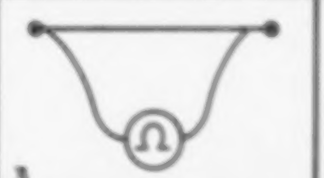

VOLTMETER
V
AMMETER
A
OHMMETER
Ω



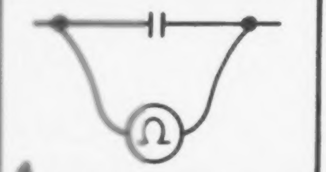
1



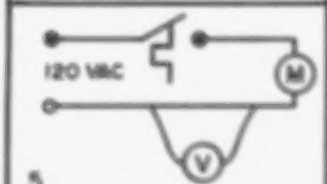
2



3



4



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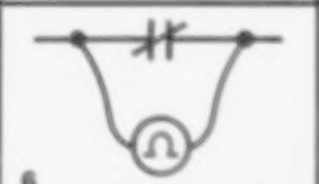
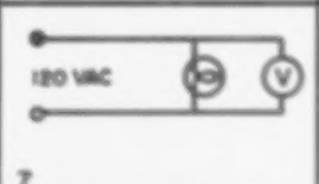


6



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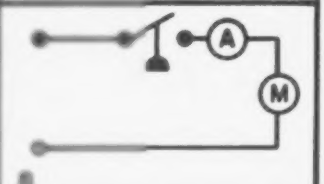

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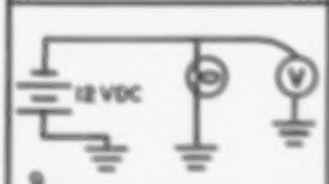

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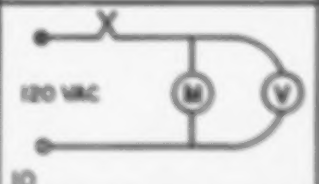

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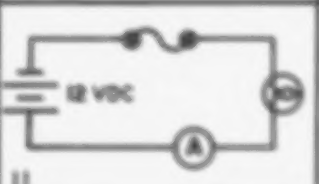

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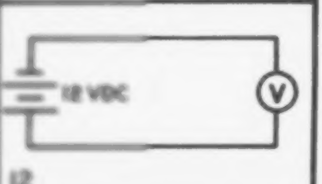

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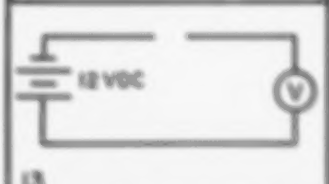

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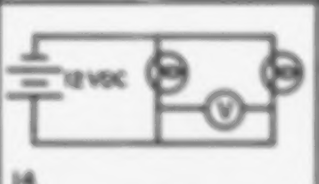

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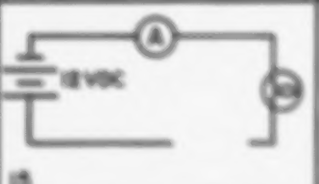

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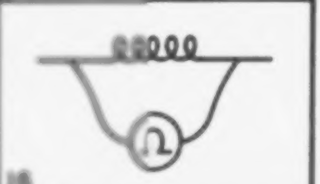

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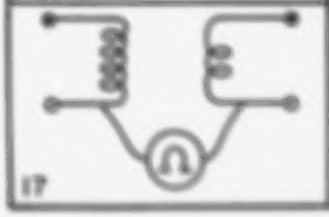

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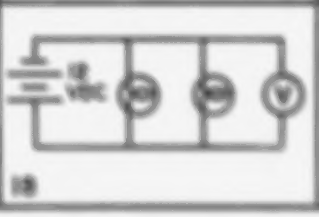

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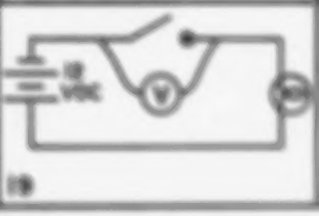

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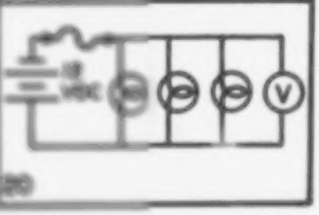


20

# ELECTRICAL MOTORS AND MOTOR STARTERS

## OBJECTIVES

Given information, identify basic facts relating to electrical motors and motor starters, by correctly answering 70% of the questions.

Using a trainer, remove and replace electric motor, with a maximum of two instructor assists.

Using a single-phase and three-phase motor trainers, reverse the motor rotation, with a maximum of two instructor assists.

Using a three-phase motor trainer, inspect and maintain motor, with a maximum of two instructor assists.

## PROCEDURE

Complete exercises as directed by instructions given for each exercise.

## EXERCISE 1
## ELECTRIC MOTORS AND MOTOR STARTERS

INSTRUCTION:

You will be graded on your ability to identify basic facts relating to electric motors and motor starters by correctly answering 70% of the responses.

(1-20) Matching

1. _____ Stationary section of a motor that contains the windings and the electromagnetic core.

2. _____ Rotating section of the motor.

3. _____ The portion of a motor that holds the bearings.

4. _____ Allow smooth rotation of the shaft.

5. _____ Provides important information about the motor.

6. _____ A device that changes electrical energy into rotating mechanical energy.

7. _____ Amount of work a motor will do without damaging it.

8. _____ Designates the type of electrical power distributed to a motor.

9. _____ Alternating current motor with only two current carrying conductors.

10. _____ Alternating current motor with three current carrying conductors.

11. _____ A type of single-phase motor with start and run windings and a centrifugal switch.

12. _____ A type of single-phase motor similar in construction to the split-phase motor with the addition of a capacitor.

13. _____ An electrical device capable of storing an electrical charge.

14. _____ Refers to a complete change in direction of alternating current.

15. _____ The amount of amperage consumed by a motor when it is first turned on.

16. _____ The amount of amperage consumed by a motor when it is delivering its rated horsepower.

17. _____ Refers to the number of shaft rotations in one minute.

18. _____ Determines the maximum allowable operating temperature of a motor.

19. _____ Refers to the clockwise or counter-clockwise rotation of a motor.

20. _____ A motor which has the ability to operate at more than one speed.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| A | Data Plate | E | Hertz | I | CW-CCW | M | Capacitor motor | Q | 1 Ø motor |
| B | RPM | F | Motor | J | Capacitor | N | Horsepower rating | R | 3 Ø motor |
| C | Phase | G | Stator | K | End bells | O | Multiple speed motor | S | F. L. A. |
| D | Rotor | H | Bearings | L | Insulation class | P | Split-phase motor | T | L. R. A. |

(21-33) Using the data plate illustrated in the figure below, enter the information in the following blank spaces to adequately identify motor installation and operation data.

21. Manuacturer's name ______________________________

22. Horsepower Rating ____________________

23. Rating Temperature at 60 Hz. ________________

24. RPM at 50 Hz. ________________

25. RPM at 60 Hz. ________________

26. Hertz (Hz.) ____________ or ____________

27. Number of phases ____________

28. Voltages motor will operate at __________/__________/__________

29. Full load amperage (F.L.A.) at 220 VAC: 60 Hz. ____________________

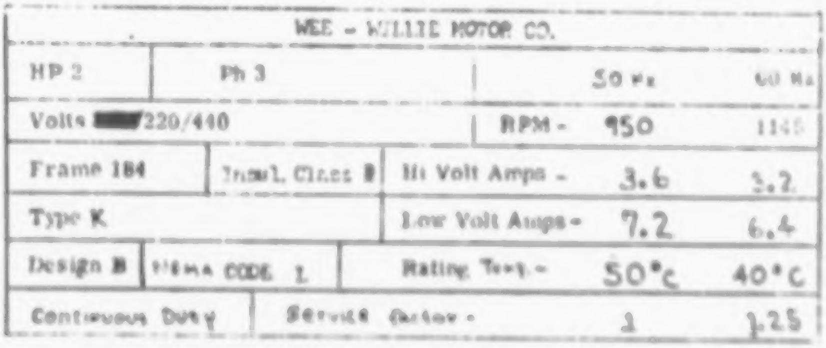
30. Full load amperage (F.L.A.) at 440 VAC: 60 Hz. ____________________

31. National Electrical Manufacturers Association Code ____________________

32. Duty Rating ________________

33. Service factor at 60 Hz. ______________________________

34. Frame No. ______



WEE - WILLIE MOTOR CO.

| | | | | |
|---|---|---|---|---|
| HP 2 | Ph 3 | | 50 Hz | 60 Hz |
| Volts [redacted]220/440 | | RPM - | 950 | 1145 |
| Frame 184 | Insul. Class B | Hi Volt Amps - | 3.6 | 3.2 |
| Type K | | Low Volt Amps - | 7.2 | 6.4 |
| Design B | NEMA CODE L | Rating Temp. - | 50°C | 40°C |
| Continuous Duty | | Service factor - | 1 | 1.25 |

Questions 35 through 40 are related to motor starters and overload protectors. Use the tables in the following figures and the motor data plate to determine the correct overload unit for each brand of motor starter and write the number in the blank spaces provided.

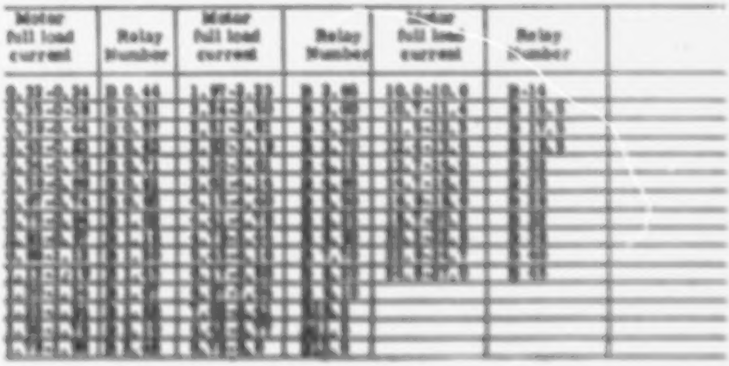
35-37 Check the motor date plate shown on Page 6-2; if the motor is connected to low voltage; 60 Hz., what number overload would be used? Use Motor Starter Overload Protector Tables.

35. Square D No. ____________________
36. Allen Bradley No. ____________________
37. Cutler-Hammer No. ____________________ (Use size 1 starter)

38-40 Check the motor data plate shown on Page 6-2; if the motor is connected to high voltage; 60 Hz., what number overload unit would be used? Use Motor Starter Overload Protector Tables.

38. Square D No. ____________________
39. Allen Bradley ____________________
40. Cutler-Hammer No. ____________________ (Use size 1 starter)

## MOTOR STARTER OVERLOAD PROTECTOR TABLES



| Motor full load current | Relay Number | Motor full load current | Relay Number | Motor full load current | Relay Number | |
|---|---|---|---|---|---|---|

Square D Table

| Heater Type No. | Full load Amps | Heater Type No. | Full load Amps | Heater Type No. | Full load Amps | Heater Type No. | Full load Amps |
|---|---|---|---|---|---|---|---|
| N 2 | 0.48 | N 11 | 1.45 | N 20 | 3.47 | N 29 | 8.35 |
| N 3 | 0.59 | N 12 | 1.62 | N 21 | 3.88 | N 30 | 9.13 |
| N 4 | 0.74 | N 13 | 1.77 | N 22 | 4.29 | N 31 | 10.5 |
| N 5 | 0.81 | N 14 | 1.93 | N 23 | 4.80 | N 32 | 11.3 |
| N 6 | 0.89 | N 15 | 2.16 | N 24 | 5.22 | N 33 | 12.6 |
| N 7 | 0.97 | N 16 | 2.41 | N 25 | 5.76 | N 34 | 14.3 |
| N 8 | 1.11 | N 17 | 2.66 | N 26 | 6.41 | | |
| N 9 | 1.22 | N 18 | 2.90 | N 27 | 7.02 | | |
| N 10 | 1.31 | N 19 | 3.18 | N 28 | 7.74 | | |

CA-021A

Allen Bradley Table

HEATER COIL SELECTION TABLES

| For Size 1 Starter | | | | For Size 2 Starter | | For Size 3 Starter | | For Size 4 Starter | |
|---|---|---|---|---|---|---|---|---|---|
| Ampere Range | Catalog No. | Ampere Range | Catalog No. | Ampere Range | Catalog No. | Ampere Range | Catalog No. | Ampere Range | Catalog No. |
| .157-.177 | H1101 | 2.20-2.45 | H1024 | 3.90-4.35 | H1028 | 8.72-9.87 | H1035 | 19.5-21.9 | H1042 |
| .178-.198 | H1102 | 2.46-2.74 | H1025 | 4.36-4.81 | H1029 | 9.88-10.8 | H1036 | 22.0-24.7 | H1043 |
| .199-.223 | H1103 | 2.75-3.07 | H1026 | 4.82-5.36 | H1030 | 10.9-12.0 | H1037 | 24.8-29.0 | H1044 |
| .224-.249 | H1104 | 3.08-3.43 | [illegible] | 5.37-5.96 | H1031 | 12.1-13.5 | H1038 | 29.1-31.9 | H1045 |
| .250-.280 | H1105 | 3.44-3.81 | H1027 | 5.97-6.63 | H1032 | 13.6-15.0 | H1039 | 32.0-36.1 | H1046 |
| .281-.315 | H1106 | 3.82-4.27 | H1028 | 6.64-7.41 | H1033 | 15.1-16.8 | H1040 | 36.2-40.7 | H1047 |
| .316-.353 | H1107 | 4.28-4.71 | H1029 | 7.42-8.23 | H1034 | 16.9-19.1 | H1041 | 40.8-45.2 | H1048 |
| .354-.395 | H1108 | 4.72-5.24 | H1030 | 8.24-9.19 | H1035 | 19.2-21.6 | H1042 | 45.3-52.4 | H1049 |
| .396-.445 | H1109 | 5.25-5.87 | H1031 | 9.20-10.3 | H1036 | 21.7-24.5 | H1043 | 52.5-59.2 | H1050 |
| .446-.499 | H1110 | 5.88-6.48 | H1032 | 10.4-11.4 | H1037 | 24.6-27.8 | H1044 | 59.3-66.3 | H1051 |
| .500-.562 | H1111 | 6.49-7.27 | H1033 | 11.5-12.8 | H1038 | 27.9-31.5 | H1045 | 66.4-75.1 | H1053 |
| .563-.631 | H1112 | 7.28-8.14 | H1034 | 12.9-14.1 | H1039 | 31.6-35.5 | H1046 | 75.2-87.1 | H1054 |
| .632-.711 | H1113 | 8.15-9.03 | H1035 | 14.2-15.9 | H1040 | 35.6-40.3 | H1047 | 87.2-99.0 | H1055 |
| .712-.799 | H1114 | 9.04-10.0 | H1036 | 16.0-18.1 | H1041 | 40.4-45.6 | H1048 | 100.-113. | H1056 |
| .800-.903 | H1115 | 10.1-11.2 | H1037 | 18.2-20.4 | H1042 | 45.7-51.8 | H1049 | 114.-129. | H1057 |
| .904-1.01 | H1116 | 11.3-12.5 | H1038 | 20.5-23.3 | H1043 | 51.9-58.6 | H1050 | 130.-150. | H1058 |
| 1.02-1.13 | H1117 | 12.6-13.8 | H1039 | 23.4-26.5 | H1044 | 58.7-65.2 | H1051 | — | — |
| 1.14-1.27 | H1018 | 13.9-15.6 | H1040 | 26.6-30.3 | H1045 | 65.3-74.3 | H1052 | — | — |
| 1.28-1.43 | H1019 | 15.7-17.7 | H1041 | 30.4-34.7 | H1046 | 74.4-84.3 | H1053 | — | — |
| 1.44-1.60 | H1020 | 17.8-19.9 | H1042 | 34.8-39.6 | H1047 | 84.4-95.0 | H1054 | — | — |
| 1.61-1.79 | H1021 | 20.0-22.5 | H1043 | 39.7-45.0 | H1048 | — | — | — | — |
| 1.80-1.98 | H1022 | 22.6-25.3 | H1044 | — | — | — | — | — | — |
| 1.99-2.19 | H1023 | 25.4-27.0 | H1045 | — | — | — | — | — | — |

Cutler-Hammer Heater Table

# EXERCISE 2

## REMOVAL AND REPLACEMENT OF ELECTRIC MOTORS

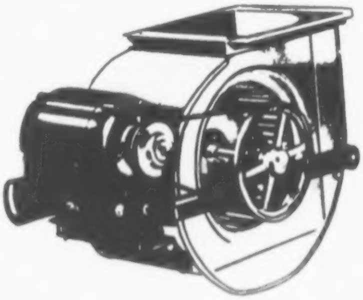
## PROGRESS CHECK 6b

INSTRUCTION:

Your instructor will demonstrate removal and replacement procedures for an electric motor. After the demonstration you will be given a furnace blower assembly and a replacement motor. You are to remove and replace the motor with a maximum of two instructor assists.

CAUTION: Remove jewelry, wear appropriate eyewear (metal rims or frames are not permitted). Most blower assemblies have sharp metal edges; be careful not to get cut. Use proper tools for the job, work carefully and ask questions if you are not sure what to do.

### REMOVE AND REPLACE ELECTRIC MOTORS



1. REMOVAL PROCEDURES:
   - (a) Inspect original motor
   - (b) Identify wiring connections
   - (c) Remove original motor

2. REPLACEMENT PROCEDURES
   - (a) Select proper replacement
   - (b) Install replacement motor

## EXERCISE 3
## REVERSING ROTATION OF ELECTRIC MOTORS

### PROGRESS CHECK 6c

INSTRUCTION:

Your instructor will demonstrate how to reverse the rotation of a single-phase and a three-phase motor. After the demonstration you will be required to perform the same task with a maximum of two instructor assists.

CAUTION: Remove jewelry, wear appropriate eyewear (metal rims or frames are not permitted). Use proper tools for the job, work carefully and ask questions if you are not sure about what to do. Instructor must check all wire connections before turning power on.

### REVERSE ROTATION OF SINGLE-PHASE MOTOR

1. Inspect motor
2. Operate motor to determine direction of rotation.
3. Interchange start winding leads (1-4).
4. Operate motor to verify change of rotation.

### REVERSE ROTATION OF THREE-PHASE MOTOR

1. Inspect motor
2. Operate motor to determine direction of rotation.
3. Interchange any two of the three power leads.
4. Operate motor to verify change of rotation.

# EXERCISE 4
# INSPECTION AND MAINTENANCE OF ELECTRIC MOTORS

## PROGRESS CHECK 4A

INSTRUCTION:

Your instructor will demonstrate how to inspect and maintain an electrical motor. After the demonstration you will be required to perform the same task with a maximum of two instructor assists. Use the inspection and maintenance checklist and place a check in the blank provided for each step completed.

CAUTION: Remove jewelry, wear appropriate eyewear (metal rims or frames are not permitted). Use proper tools, supplies and testing equipment for the job, work carefully and ask questions if you are not sure about what to do.

### INSPECTION AND MAINTENANCE CHECKLIST

__________ CLEANLINESS

__________ ELECTRICAL CONNECTIONS

__________ NOISE/VIBRATION

__________ LUBRICATION

__________ BEARINGS

__________ SHAFT END-PLAY

__________ RPM

__________ AMPERAGE

__________ VOLTAGE

__________ TEMPERATURE

## SAVE A LIFE

If you observe an accident involving electrical shock,

DON'T JUST STAND THERE - DO SOMETHING!

### RESCUE OF SHOCK VICTIM

The victim of electrical shock is dependent upon you to give him prompt first aid.

Observe these precautions:

1. Shut off the high voltage.
2. If the high voltage cannot be turned off without delay, free the victim from the live conductor.

### REMEMBER:

a. Protect yourself with dry insulating material.

b. Use a dry board, your belt, dry clothing, or other nonconducting material to free the victim. When possible **PUSH - DO NOT PULL** the victim free of the high voltage source.

c. **DO NOT** touch the victim with your bare hands until the high voltage circuit is broken.

### FIRST AID

The two most likely results of electrical shock are: bodily injury from falling, and cessation of breathing

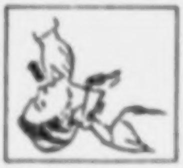
While waiting for emergency medical assistance:

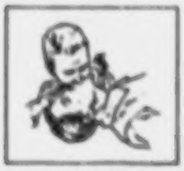
DO THESE THINGS:

1. Control bleeding by use of pressure. Use a tourniquet only as a last resort!
2. Begin **IMMEDIATELY** to use artificial respiration if the victim is not breathing or is breathing poorly:

a. Turn the victim on his back.

b. Clear the mouth and throat. (If foreign matter is present, wipe it away quickly with a cloth or your fingers.)





c. Place the victim's head in the "*sword-swallowing*" position. (Place the head as far back as possible so that the front of the neck is stretched.)

d. Hold the lower jaw up. (Insert your thumb between the victim's teeth at the midline - pull the lower jaw forcefully outward so that the lower teeth are further forward than the upper teeth. Hold the jaw in this position as long as the victim is unconscious.)

e. Close the victim's nose. (Compress the nose between your thumb and forefinger.)

f. Blow air into the victim's lungs. (Take a deep breath and cover the victim's open mouth with your open mouth, making the contact air-tight. Blow until the chest rises. If the chest does not rise when you blow, improve the position of the victim's air passageway, and blow more forcefully. Blow *forcefully* into adults, and *gently* into children.)

g. Let air out of the victim's lungs. (After the chest rises, quickly separate lip contact with the victim allowing him to exhale.)

h. Repeat steps *f* and *g* at the rate of 12 to 20 times per minute. Continue rhythmically without interruption until the victim starts breathing or is pronounced dead. (A smooth rhythm is desirable, but split-second timing is not essential.)

**DON'T JUST STAND THERE - DO SOMETHING!**

Technical Training

# Heating Systems Specialist

# CONTROLS, TROUBLESHOOTING AND OIL BURNERS

March 1983

3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

RGL: 9.27

FOR ATC COURSE USE ONLY
DO NOT USE ON THE JOB

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# EXPLANATION OF TERMS

ABSOLUTE ZERO -- Where molecular activity ceases (459.69°F).

ABSORPTION -- Process of absorbing, to take in, make a part of.

ACCESSORIES -- Items not essential, but adding to the convenience or effectiveness of something else.

ACCUMULATE -- Collect, to increase in quantity.

ADJUSTMENT -- To regulate, to bring to a more satisfactory state.

AGITATOR -- Device for shaking or stirring.

ALIGNMENT -- Putting into precise position, proper positioning or state of adjustment of parts.

ALTITUDE -- The vertical elevation of an object above sea level.

ANALYSIS -- Identification or separation of ingredients of a substance, separation of a whole into its component parts.

ANALYZER -- Device used in analysis.

ANEMOMETER -- Instrument for measuring and indicating the force or speed of the wind.

ANTHRACITE -- A hard shiny coal.

AQUASTAT -- A controlling device actuated by water temperature.

ASBESTOS -- A fire-resistant material.

ASPHYXIATION -- Death because of lack of oxygen.

ASPIRATOR -- Device used to create a suction.

ATMOSPHERIC -- Of or relating to the atmosphere.

ATOMIZATION -- Act of atomizing, breaking into fine particles.

AUTOMATIC -- Self acting.

AUXILIARY -- Providing help, functioning in a subsidiary capacity.

BAFFLE -- Use to direct flow of gases, steam or water.

BEARING -- A machine part in which a shaft or pin turns.

BIMETALLIC -- Composed of two different metals.

BINARY -- Something constituted of two things or parts.

BITUMINOUS -- Soft coal.

BLOWDOWN -- Discharge, drain partially.

BOILING -- Heated to the boiling point.

BONDING -- Adhesive or cementing material.

BTU -- British thermal unit, unit of heat measurement.

BURNER -- Part of heating unit which produces flame.

CAKING -- To form or harden into a mass.

CALIBRATION -- To determine, a mark of graduation, the act or process of calibrating.

CAPACITY -- Measure of content, maximum output.

CARBON -- An essential part of coal and oil.

CARBON DIOXIDE -- A gas consisting of one part carbon and two parts oxygen ($CO_2$).

CARBON MONOXIDE -- A gas consisting of one part carbon and one part oxygen (CO).

CATHODIC PROTECTION -- Reduction or prevention of corrosion of a metal surface using an electrical current flow.

CELSIUS -- Thermometric scale, the interval between freezing and boiling is divided into 100 degrees.

CENTIMETER -- Metric measurement equaling 0.39 inch; 0.01 of a meter.

CENTRIFUGAL -- Going or acting in a direction away from a center or axis.

CHARACTERISTIC -- Traits, qualities or properties.

CHIMNEY -- Vertical structure enclosing a flue that carries off combustion gases.

CIRCUIT -- The complete path of an electrical current usually including the source of electric energy.

CIRCULATE -- To move, usually in a circle, circuit or orbit.

CLASSIFICATION -- Division of a larger category.

CLASSIFIED -- Divided into classes.

COEFFICIENT -- A number that serves as a measure of some property or characteristic.

COMBINATION -- Two or more, together.

COMBUSTION -- Burning.

COMPENSATING -- Making up for something.

COMPONENT -- A part of.

COMPOSITION -- Made up of.

CONCENTRATION -- Strength (as in strong tea).

CONDENSATION -- Act of steam turning back into water.

CONDUCTION -- The act of conveying heat through an object.

CONDUCTIVITY -- Ability to conduct.

CONSTANT -- Always or lasting.

CONSUMER -- A unit which uses steam or hot water.

CONSUMPTION -- The usage of steam or hot water.

CONTROL -- Having power over.

CONVECTION -- The act or process of conveying.

CORROSION -- Act of eating away by degrees.

COUNTERWEIGHT -- An equivalent poundage.

COUPLING -- A device that serves to connect ends of adjacent parts.

CSG -- Commercial Standard Grade (grades of oil).

CYCLE -- A sequence of a recurring succession of events.

DAMPER -- A plate used to regulate the flow of air or gases.

DE-ENERGIZE -- Remove the energy from.

DEMARCATION -- The set limits of.

DENSE -- Having high opacity, crowding together of parts, thick.

DESIGN -- Plan or purpose.

DETERIORATION -- The loss of strength, form or usefulness; to grow worse in quality.

DEVICE -- A piece of equipment or mechanism designed to serve a purpose.

DIAMETER -- A straight line through the center of a circle.

DIAPHRAGM -- Thin membrane divider or partition.

DIFFERENTIAL -- The difference between two points.

DIFFUSERS -- Device used to regulate velocity.

DIFFUSING -- The act of regulating the velocity of.

DILUTES -- Reducing the strength of.

DISASSEMBLING -- Taking apart.

DISPLACEMENT -- The volume displaced by a piston.

DISSIPATE -- To cause to spread out or spread thin to the point of vanishing.

DISTILLATE -- Light grade oils produced by distillation.

DISTINCTIVE -- Having or giving style.

DISTRIBUTION -- Giving out or supplying portion of.

DOMESTIC -- Relating to the home or family.

DOWNDRAFT -- Supply of air received down through a chimney.

DRAFT -- A supply of air for combustion, a current of air in a closed-in space.

EFFICIENCY -- Measurement of operation or ability.

ELECTRIC/ELECTRICAL -- Pertaining to something operated by electricity.

ENERGIZE -- Give energy to.

EQUALIZE -- To make equal.

EQUILIBRIUM -- Balance.

EQUIPMENT -- Implements used in an operation or activity.

ESSENTIAL -- Necessary.

EVAPORATE/EVAPORATING -- To pass off in vapor or invisible minute particles.

EXCESSIVE -- Going beyond a limit.

EXCHANGER -- Device used to change heating mediums.

EXHAUST -- Already used once, to discharge, to draw off.

EXPANSION -- Increase in size or volume.

EXTINGUISHED -- Put out or killed.

FAHRENHEIT -- A thermometric scale on which the boiling point is 212° and freezing is 32°.

FERRULE -- Ring or metal put around a slender tube or shaft to strengthen it or prevent it from splitting.

FIXED CARBON -- Nonvolatile carbon in coal and oil.

FLARED -- A spreading outward.

FLEXIBLE -- Bendable or pliable.

FLUCTUATION -- Changing from a norm.

FLUE -- An enclosed passageway for conveying combustion gases to the outer air.

FLUE GAS -- Combustion gas.

FRACTIONAL -- Process for separating components of a mixture through differences in physical and chemical properties.

FURNACE -- Where initial combustion and burning of fuel takes place.

GAUGE -- Instrument with a graduated scale for measuring or indicating quantity.

GRAVITY -- Force that draws objects toward the center of the earth.

GROUNDING -- The act of or an object that makes an electrical connection with the earth.

HEADER -- Pipe or tube shared by two or more objects or devices.

HOPPER -- Usually funnel-shaped receptacle for delivering coal.

HORIZONTAL -- Parallel to the horizon.

HUMIDIFICATION -- Act or process of using a humidifier.

HUMIDIFIER -- Device used to increase the humidity.

HUMIDISTAT -- Device used to sense humidity.

HUMIDITY -- Moisture in the air.

IGNITION -- Act of setting on fire.

IMPURITIES -- Something not pure or makes something else not pure.

INDUSTRIAL -- Relating to industry.

INERT -- Having no inherent power of action, motion or resistance.

INFILTRATION -- To pass into or through by filtering or permeating.

INOPERATIVE -- Not functioning.

INSERTION -- Act or process of inserting.

INSULATE -- Protect or cover.

INTENSITY -- The magnitude of force or energy.

INTERMITTENT -- Coming and going at intervals.

LATENT HEAT -- Heat that cannot be measured with or by a thermometer.

LIBERATES -- Sets free.

LIGNITE -- A brownish black, woody structured coal.

LPG -- Liquefied petroleum gases.

LONGITUDINAL -- Placed or running lengthwise.

LOUVER -- An opening provided with slanted fixed or movable fins to allow flow of air.

LUBRICATE -- To make slippery, usually with grease or oil.

MANIFOLD -- Header.

MANUAL -- Operated by hand.

MECHANICAL -- Operated by a machine.

MECHANISM -- Mechanical operation or action.

MEDIUM -- A means of effecting or conveying something.

MIXTURER -- Matter consisting of two or more components in varying proportions that retain their own properties.

MODULATING -- A regulating according to measure or measure or proportion.

MOISTURE -- Wetness.

NON-RECESSED -- Not set into.

NOZZLE -- A projecting spout, terminal discharging pipe.

OBSTRUCTION -- Blockage.

ORIFICE -- Hole or opening.

OXYGEN -- A gas without color, taste or ordor, and is a chemical element (O).

PARTICLE -- One of the minute subdivisions of matter.

PASSAGE -- Channel, course, tunnel or corridor.

PERIMETER -- The boundary of a closed plane figure.

PERIODIC -- Fixed interval between set times.

PERTINENT -- Relevant or applicable.

PETROLEUM -- An oily flammable bituminous liquid.

PILOTSTAT -- Conrol on the fuel line of a pilot.

PIPETTES -- A narrow glass tube into which the liquid is drawn by suction.

PLENUM -- An enclosed space in which the air pressure is greater than the outside atmosphere.

PNEUMATIC -- Moved or worked by air pressure.

POLLUTION -- Impure or unclean.

PORCELAIN -- Ceramic that is hard, translucent and white.

POSITIVE -- Affirmative.

PRECIPITATOR -- Device used to cause to separate or condense.

PREDETERMINED -- Decided or chosen beforehand.

PRELIMINARY -- Something that precedes.

PRESSURE/PRESSURIZING -- Force exerted over a surface divided by its area.

PROCESS -- A series of actions coming to an end.

PROPELLER -- A device that drives or forces forward or onward.

PROPORTIONAL -- Having the same or constant ratio.

PULVERIZED -- Reduced to very small particles.

PURGE -- Clean out.

QUANTITY -- Amount (how many).

RADIANT -- Emitted or transmitted by radiation.

RADIATION -- Energy radiated in waves or particles.

RADIATOR -- Nest of pipes or tubes used to heat by radiation.

REASSEMBLE -- Put back together.

RECTANGULAR -- Having or resembling the shape of a rectangle.

REFERENCE -- Consultation of sources or information.

REFRACTORY -- Heat resisting nonmetallic ceramic material.

REGULATE -- To control something.

REGULATOR -- Device which regulates.

RELATIVE -- A thing having a connection with or necessary dependence on one other thing.

RESIDUAL -- A residue or substance left.

RESPONSE -- Reply or reaction.

RESTRICT -- To limit.

RETURN -- To bring, send or come back to the starting point or place.

ROTATION/ROTATING -- The turning of a body on an axis.

SATURATION -- Moisturizing to the maximum limit.

SEMIBITUMINOUS -- A type of coal.

SENSIBLE HEAT -- Heat that can be felt or sensed.

SHUTOFF -- Something that stops the flow of gas, water or oil.

SLAGGING -- The flowing together of coal impurities.

SMOKE PIPE -- The vent pipe used to remove smoke and gases from the firebox of a furnace or boiler.

SOLENOID -- An electromagnetic valve or switch.

SOLUTION -- A liquid containing a dissolved substance.

SOOT -- Black substance formed by combustion or separated from fuel during combustion.

SPONTANEOUS -- Without external stimulus.

STABILIZER -- Substance that prevents chemical change.

STATIC ELECTRICITY -- Electricity produced by atmospheric conditions or various natural or man-made electrical disturbances.

STATIONARY -- Fixed, not moving.

STOKER -- A machine for feeding a fire.

STRAINER -- Device used to remove impurities from water and steam lines.

STRATIFICATION -- Act or process of stratifying.

SUPPLY -- To provide for.

SYNTHETIC INTOXICATION -- Artificial intoxication.

SYSTEM -- An assemblage or combination of things or parts forming a complex or unitary whole.

TEMPERATURE -- A measurement of heat in degrees Fahrenheit or Celsius.

TENSION -- Condition or degree of being stretched to stiffness.

THERMOCOUPLE -- Thermoelectric couple used to measure temperature differences.

THERMOMETER -- Instrument to measure temperature.

THERMOPILE -- Multi-thermoelectric couples.

TRANSFER -- Move something from one place to another.

TROUBLESHOOTING -- Looking, in a logical sequence, for a problem.

TURBULENT -- Causing unrest, violence or disturbance.

TUYERES -- Nozzles through which an air blast is delivered.

VAPORIZATION -- Act, process or state of being vaporized.

VAPORIZING -- To convert, by heating or spraying, into a fine mist or vapor.

VELOCITY -- Quickness of motion.

VELOMETER -- Device used to measure velocity.

VENTURI -- Funneled tube used to measure flow.

VISCOSIMETER -- Device used to measure viscosity.

VOLATILE -- Readily evaporates at low temperature.

VOLUME -- Space occupied, measured in cubic units.

VOLUMETRIC -- Relating to the measurement of volume.

# ELECTRICAL AND ELECTRONIC CONTROLS

## OBJECTIVES

1. Explain facts about purpose, use of and principles of operation of electrical controls.
2. Adjust electrical controls to assure proper operation.
3. Identify basic facts relating to electronic controls.
4. Explain the facts about theory of operation and use of pneumatic controls.
5. Explain basic procedures to remove, replace, adjust, maintain and troubleshoot pneumatic controls and equipment, and how to install pneumatic control pipes, tubes and valves.

## INTRODUCTION

Because of the wide variety of equipment used by the heating man you must become familiar with the different types of controls used to operate this equipment.

In this study guide we will cover the different types of electric, electronic and pneumatic controls. It will be done in three sections.

SECTION I - Electrical Controls

SECTION II - Electronic Controls

SECTION III - Pneumatic Controls

## SECTION I

## Electrical Controls

### OBJECTIVE

To help you understand the purpose, use, and operation of electric controls.

### INTRODUCTION:

It has been found that the basic control concepts, taken for granted by personnel working in the control industry, are not generally known or understood by the layman.

### INFORMATION:

### Control Theory

### Purpose of Electrical Controls

Electric controls enable man to complete his tasks better and at lower operating cost than if the same work were done with manual controls. Their application is widespread. It would be difficult to enumerate all of the uses of electric controls, but a few examples are given below to indicate the scope of the subject. Uses range from the simple controls in home appliances and automotive devices through domestic heating and commercial comfort air conditioning to commercial and industrial process controls.

The simple thermostats in the electric flat iron and electric toaster are elementary examples of electric controls. The numerous automatic controls used in water heaters, automatic clothes washers and dryers, and dishwashers suggest somewhat more complicated applications. The electric thermostat which starts and stops the oil or gas burner in the home is well known. Equally important, but not so well known are the various limit and safety controls necessary to the safe operation of the burner.

High speed, precision mass production depends on electric controls. Some of these systems are quite complex. Uniformity of manufacturing conditions and product are essential. Electric controls provide the necessary uniformity.

Among the important fields making use of electric controls are heating, ventilating and air conditioning. From earliest times, comfort has been a goal of man so that he can live and work at any time in all parts of the world.

First came crude shelter, later a fire to warm the shelter. Both shelter and heating means gradually improved, but automatic control for regulating heat did not begin to appear until the end of the nineteenth century. Today, we not only expect the places where we live and work to be heated, but cooled when needed as well. We expect and get precise comfort conditions with safety and efficiency.

### Use of Electrical Controls

Electric controls are used on heating systems to accomplish one or more of the following:

a. Insure required conditions of temperature, pressure, or humidity.

b. Provide safety protection by preventing operation of mecahnical equipment when such operation would be harmful or hazardous.

c. Insure economical results by providing steady-state conditions and preventing excessive operation of the system.

d. Eliminate human error in heating equipment control.

## Principles of Operation

Electric controls reduce the need for manual control, and maintain a more stable space condition. They automatically operate the heating equipment, and safeguard it against failure of one or more units in the control system. In order to provide close control, these delicate instruments require fine adjustment. Controls are provided with rugged exteriors for protection of the inner parts. However, care should be taken to avoid rough handling.

### Two-position controls

In the heating field this type of control is probably the most commonly used. They provide either full delivery or no delivery of the source of power and are sometimes called "on-off" control. A good example of this type of control is a room light switch. Either the lights are on or they are off.

### Modulating Controls

Modulating controls differ from the two-position controls in that they are never just off or on. They can be either on, off, or any place in between.

An example of a modulating control is the temperature control on an electric stove. Lets say for instance that you wanted to cook a steak on the stove. First you turn the stove on and heat it up. Once the stove gets hot you place your steak on and begin to cook it. If the steak begins to cook too fast you turn down the heat to a point where the steak cooks at the proper rate. You continue this until the steak is done. This is known as manual control. With electric controls this can be done either manually or automatically.

### Temperature-Responsive Devices

Many automatic control units such as the thermostat, limit control, fan switch, etc., must be responsive to temperature changes. A temperature change actually causes the electrical contacts within each unit to open and close. This action is an indicating signal that is transmitted to the primary control for specific action, such as starting or stopping the operation of the heating plant.

BIMETALLIC STRIP. An automatic control unit is sometimes equipped with a straight bimetallic strip to open and close the contacts. The strip is made by bonding together two pieces of dissimilar metals such as brass and invar, as shown in figure 1-1. This strip does not deflect or bend below a predetermined temperature. However, when the strip is heated it will tend to bend in the direction of the metal which has the least amount of expansion, such as shown in figure 1-2. Actually, an electrical switch is constructed, as shown in figure 1-3 by welding two electrical connections and contacts to the arrangement. This switch can be used to control the electrical circuit by responding to temperature changes. This is the basic principle of operation for many temperature-responsive automatic units.

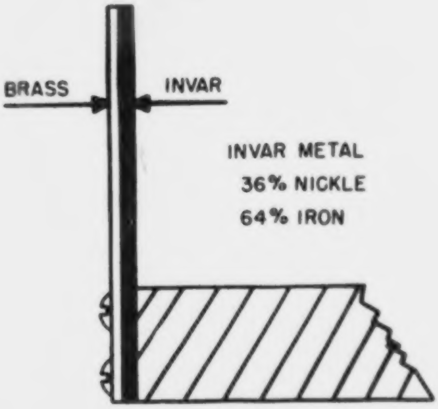

BRASS
INVAR
INVAR METAL
36% NICKLE
64% IRON

Figure 1-1. A Bimetallic Strip

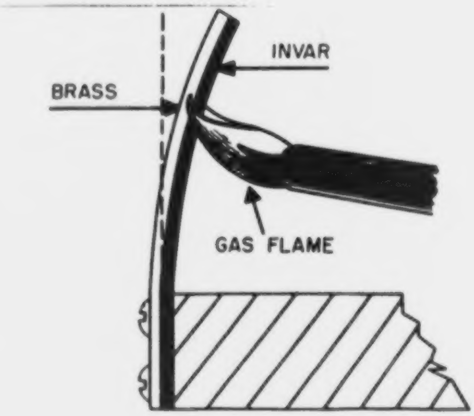

INVAR
BRASS
GAS FLAME

Figure 1-2. The Bimetallic Strip Being Heated

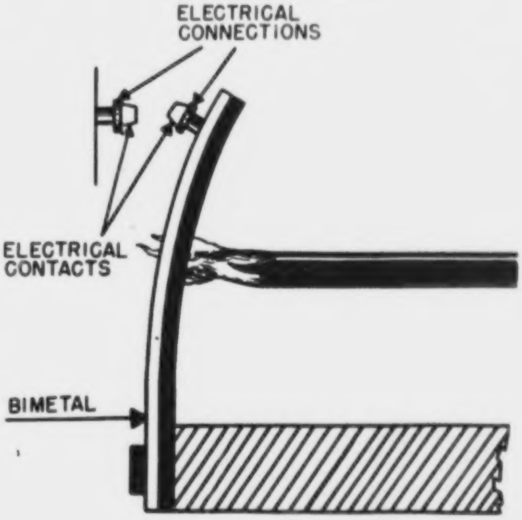

ELECTRICAL CONNECTIONS
ELECTRICAL CONTACTS
BIMETAL

Figure 1-3. A Bimetallic Electrical Switch

Some automatic units, however, can be operated by a bimetallic strip in the form of a spiral, a U-shape, a Q-shape, or even in the form of a helix, as shown in the illustrations in figure 1-4.

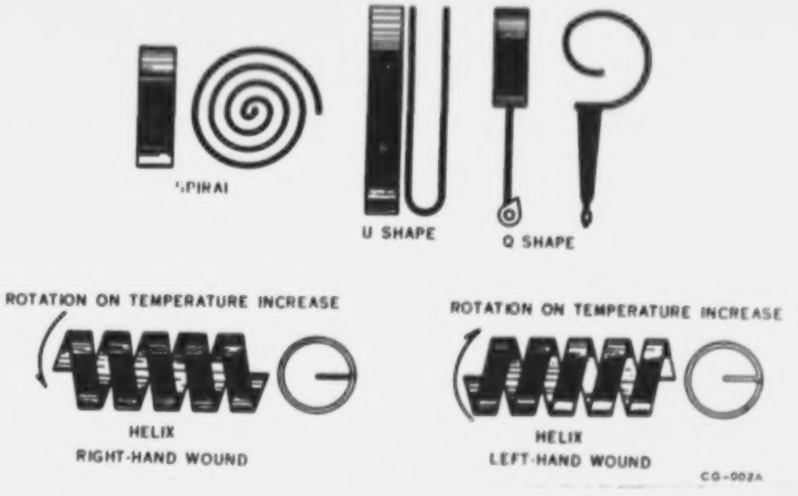


Figure 1-4. Shapes of Bimetallic Strips

THE VAPOR-TENSION DEVICE. The vapor-tension principle is used to operate some types of automatic control units. This is a commonly used type of temperature measuring device, in which the effects of temperature changes are transmitted into motion by means of a highly volatile liquid. The most vapor-tension device of this type is the simple compressible bellows, such as that shown in figure 1-5. It is made of brass and is partially filled with alcohol, ether or some other high-volatile liquid not corrosive to brass.

When the temperature around the bellows increases, the heat gasifies the liquid causing the bellows to expand and open a set of electrical contacts. When the bellows cool again, they contract and close the electrical contacts.

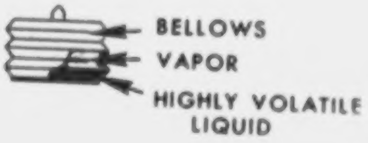


Figure 1-5. The Bellows

THE REMOTE-BULB DEVICE. All liquid-filled devices are not limited to just the simple bellows such as that described above. There are also remote-built type devices that not only have a bellows, but they have a capillary tube and a liquid-filled bulb such as that shown in figure 1-6. When the liquid in the bulb is heated, part of it gasifies and forces its way through the capillary tube into the bellows. The increase in pressure inside the bellows causes them to expand and open or close a set of electrical contacts. When the bulb cools, the gas liquifies and causes a decrease in pressure in the bellows. This action allows the bellows to contract and open or close the set of electrical contacts.

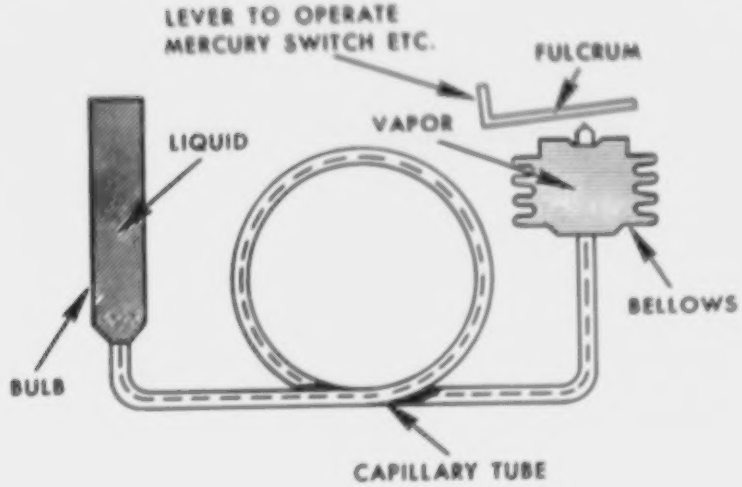

LEVER TO OPERATE
MERCURY SWITCH ETC.
FULCRUM
LIQUID
VAPOR
BELLOWS
BULB
CAPILLARY TUBE

Figure 1-6. Remote-Bulb Device

### Thermostats

The thermostat is a temperature-sensing device that responds to changes in ambient temperature and reacts to them by sending a suitable signal in the primary control. This is done by closing or opening an electrical switch within the thermostat.

Electric thermostats may be either low-voltage, designed to operate on 25 volts or less, or line-voltage, operating directly from the power coming in (110 or 220 volts). The main difference between the two is that when using a low-voltage thermostat you will either control a relay or a low-voltage solenoid. When using a line voltage thermostat you can control the piece of equipment directly.

The internal mechanism of the thermostat is an electric switch which is activated by a temperature-sensing element to make or break an electrical contact. Figure 1-7 illustrates the internal mechanism of a low-voltage room thermostat. The temperature-sensing element here is a bellows. It expands or contracts as the temperature rises or falls, and causes the switch to operate.

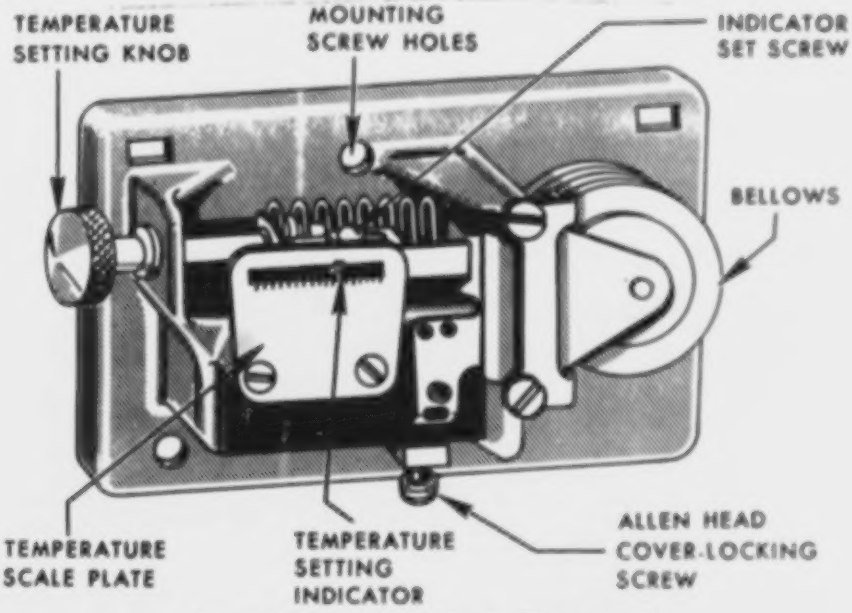

TEMPERATURE
SETTING KNOB
MOUNTING
SCREW HOLES
INDICATOR
SET SCREW
BELLOWS
TEMPERATURE
SCALE PLATE
TEMPERATURE
SETTING
INDICATOR
ALLEN HEAD
COVER-LOCKING
SCREW

Figure 1-7. A Bellows Thermostat

Because the thermostat is a temperature actuated device it must be located so as to represent that part of the building in which the heat is needed to maintain a comfortable temperature. The thermostat must be installed where it will register, as closely as possible, the average ambient temperature to be controlled. It will not operate satisfactorily unless free air circulates around its temperature sensing element. The preferred location is on an inside wall and not more than four and one-half feet above the floor. It should be installed so that it will be exposed to the free circulation of air, but not to hot or cold drafts, or direct rays of the sun or radiant heat from a fireplace.

## Safety Pilots (Pilotstats)

Safety pilots, or pilotstats as they are sometimes called, are safety devices that are installed on gas fired equipment to shut off the gas to the main burner if the pilot light should ever go out. They can be broken down into two distinct types, (1) pilotstat valves and (2) pilotstat relays. They both require the use of a thermocouple. The main difference between the two is that one operates an electrical circuit and the other operates a valve.

The pilotstat shown in figure 1-8 will break the circuit to the main gas control valve causing it to close or remain closed if the pilot flame is extinguished. This action is satisfactory for use on standard gas installations.

The pilotstat shown in figure 1-8 incorporates a thermocouple which creates current flow when heated by the pilot flame to energize an electromagnet that holds the contacts of an electric switch closed. In case of pilot failure, current is no longer generated and the electric switch contacts open. The ON-OFF indicator shows the contact position of the switch.

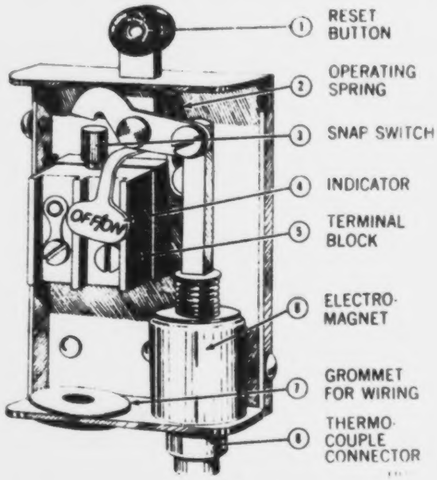


Figure 1-8. Thermoelectric Pilotstat

A distinctive feature of this pilotstat is the design of the manual reset button. Pressing the button breaks the circuit. The snap switch cannot make contact until the pilot burner is operating properly and the reset button released.

The valve-type pilotstat and pilot burner in addition to providing a constant pilot flame, will shut off the gas supply to the main burner AND PILOT, if the pilot flame is extinguished. This feature is required on L.P.G. installations and is recommended for the other types of gas.

The valve-type pilotstat, shown in figure 1-9, provides direct control of the main burner gas supply, independent of the operating valve controlled by the room thermostat. Since the pilot gas is taken from a pilot outlet in the pilotstat, pilot gas is also under complete control.

The pilotstat valve is operated by an electromagnet which receives current from a thermocouple which energizes the electromagnet holding the gas valve open. If the pilot flame is extinguished, current is no longer generated by the thermocouple and the gas valve closes.

Another type of pilotstat used is one which incorporates both the valve and the relay. See figure 1-10. In this type of pilotstat whenever the thermocouple stops producing enough current to keep the coil energized both the electrical circuit and the gas supply are cut off, thereby assuring complete shutdown of the equipment.

Safety pilots come in many different types, depending on the manufacturer and application required. Different manufacturers call them different names also, but no matter whey they are called, the operation is basically the same.

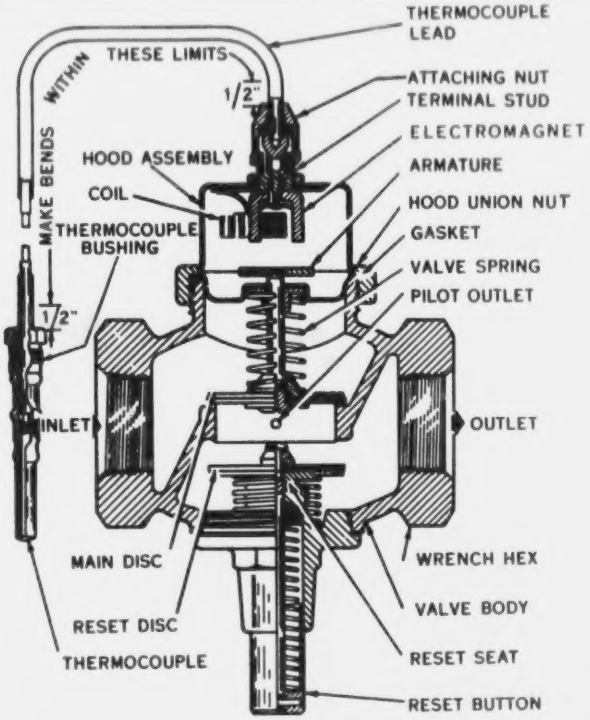

THERMOCOUPLE LEAD
THESE LIMITS
WITHIN
MAKE BENDS
1/2"
ATTACHING NUT
TERMINAL STUD
ELECTROMAGNET
HOOD ASSEMBLY
ARMATURE
COIL
HOOD UNION NUT
THERMOCOUPLE BUSHING
GASKET
VALVE SPRING
PILOT OUTLET
1/2"
INLET
OUTLET
MAIN DISC
WRENCH HEX
VALVE BODY
RESET DISC
RESET SEAT
THERMOCOUPLE
RESET BUTTON

Figure 1-9. Valve Pilotstat

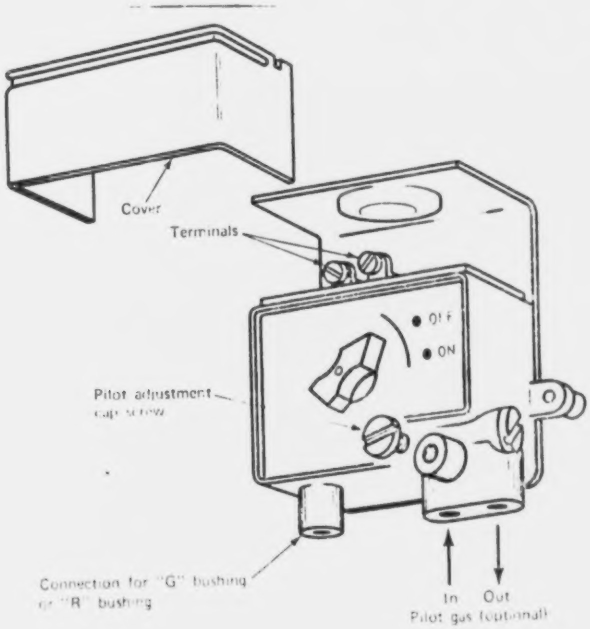

Cover
Terminals
OFF
ON
Pilot adjustment cap screw
Connection for "G" bushing or "R" bushing
In
Out
Pilot gas (optional)

Figure 1-10. Manual reset pilotstat relay

## Limit Controls

The limit control has a distinct purpose, and that is to control the operation of the burner so that the temperature or pressure of the heating system will never exceed safe operating limits. Its function is distinctly for safety control.

LIMIT CONTROL FOR A WARM-AIR HEATING SYSTEM. The limit control for the warm air heating system responds to temperature increases inside the furnace that is over and above the preset limit. This preset limit is controlled by the limit control, and is wired in series with the burner circuit. The contacts in the limit control are normally closed (NC) and open when the temperature rises too high in the bonnet, upper part of the furnace).

Many limit controls have a dial setting that is similar to the face of a clock. You adjust the setting to maintain the proper limits that you would want. The normal temperature range is 175° to 200°F. See figures 1-11 and 1-12.

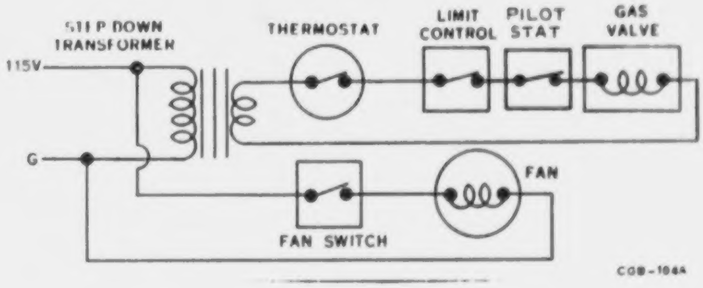

STEP DOWN TRANSFORMER
115V
G
THERMOSTAT
LIMIT CONTROL
PILOT STAT
GAS VALVE
FAN
FAN SWITCH
COB-104A

Figure 1-11. Schematic diagram of limit control in the circuit.

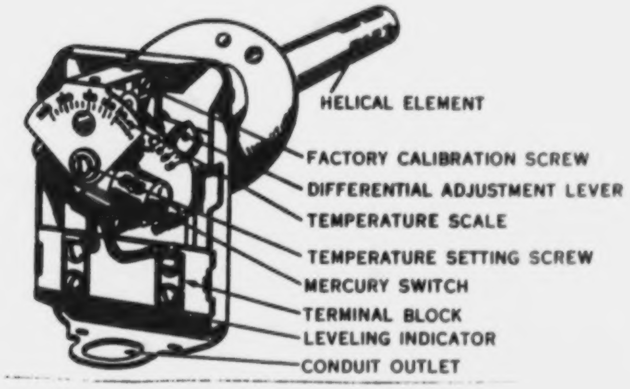

HELICAL ELEMENT
FACTORY CALIBRATION SCREW
DIFFERENTIAL ADJUSTMENT LEVER
TEMPERATURE SCALE
TEMPERATURE SETTING SCREW
MERCURY SWITCH
TERMINAL BLOCK
LEVELING INDICATOR
CONDUIT OUTLET

Figure 1-12. Limit Switch

## Primary Controls

Primary controls are actuating devices which operate heating equipment in response to signals received from thermostats. Often the primary control is a simple switching device which closes and opens the main circuit.

PRIMARY CONTROL FOR GAS. The primary control for a gas burner is a valve that opens or closes in response to the thermostat signals. Listed below are some of the different types.

SOLENOID OR MAGNETIC GAS VALVE. The solenoid gas valve shown in figure 1-13 opens when electric energy is applied directly to the solenoid. This signal, which is received from the thermostat, causes the solenoid to act as an electromagnetic which lifts a plunger causing the valve to open. The valve closes by gravity when the electrical circuit is broken by the thermostat or limit control. This type of valve is used for small installations.

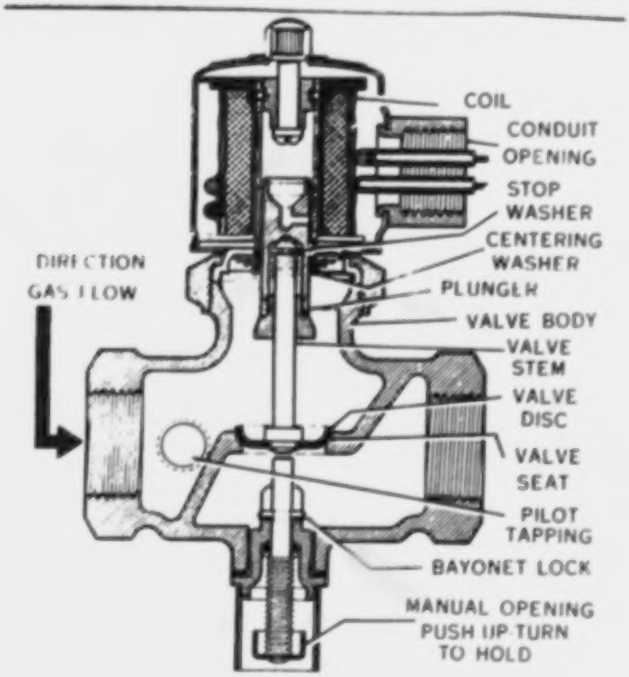

COIL
CONDUIT OPENING
STOP WASHER
CENTERING WASHER
DIRECTION GAS FLOW
PLUNGER
VALVE BODY
VALVE STEM
VALVE DISC
VALVE SEAT
PILOT TAPPING
BAYONET LOCK
MANUAL OPENING PUSH UP TURN TO HOLD

Figure 1-13. Solenoid Gas Valve

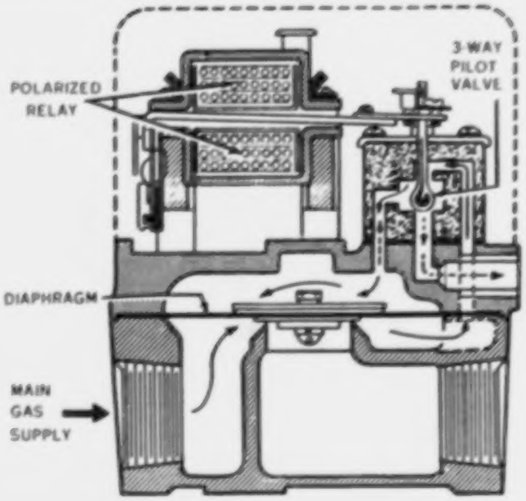

POLARIZED RELAY
3-WAY PILOT VALVE
DIAPHRAGM
MAIN GAS SUPPLY

Figure 1-14. A Diaphragm Gas Valve

DIAPHRAGM GAS VALVE. The diaphragm gas valve, figure 1-14 may be used interchangeably with the solenoid gas valve. In this type of diaphragm valve, the polarized relay energizes and opens the three-way valve allowing the gas to flow out of the upper chamber of the unit. Reducing the pressure in the upper chamber in this manner causes the diaphragm to flex upward and open the gas valve. When the polarized relay is de-energized, the three-way pilot valve allows gas to flow into the upper chamber increasing the pressure, and thereby closing the gas valve.

MOTORIZED GAS VALVE. The motorized gas valve differs from the solenoid and diaphragm gas valve in that it has a motor to control its position. When the motor is energized, it holds the valve open, when it is de-energized, a return spring closes the valve.

PRIMARY CONTROLS FOR OIL. The oil burner primary control combines four controls: a starting control, an ignition control, a combustion safety control, and a delayed-action control.

--Starting Control. Closes motor and ignition circuits when thermostat calls for heat.

--Ignition Control. Breaks motor and ignition circuits and stops burner if fuel oil fails to ignite when burner motor first starts.

--Combustion Safety Control. Breaks motor and ignition circuits and stops burner, if the flame fails after burner has been operating, to prevent unignited oil from flooding the combustion chamber.

--Delayed-Action Control. Keeps the oil valve closed until all safety devices are in a normal starting position. For example, if flame failure causes an out-fire cutoff operation, the delayed-action switch keeps the oil valve closed, regardless of thermostat requirements, until stack temperature has dropped to a predetermined safe level.

See figures 1-15 and 1-16 showing oil burner primary control (Stack Switch), and a wiring diagram for an oil-fired forced warm-air unit.

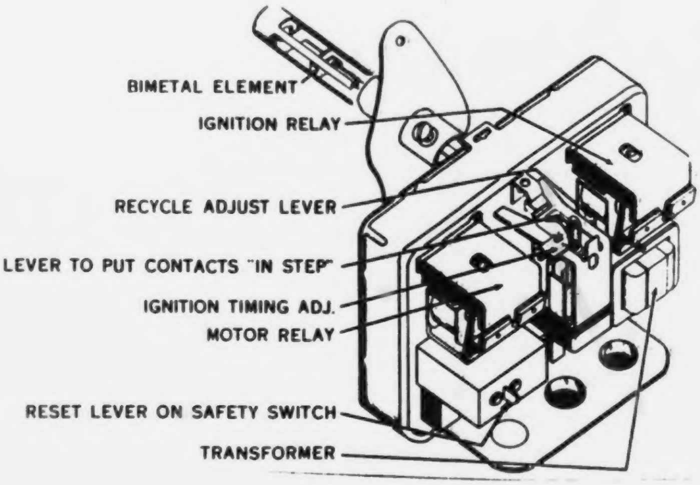

BIMETAL ELEMENT
IGNITION RELAY
RECYCLE ADJUST LEVER
LEVER TO PUT CONTACTS "IN STEP"
IGNITION TIMING ADJ.
MOTOR RELAY
RESET LEVER ON SAFETY SWITCH
TRANSFORMER

Figure 1-15. Oil Burner Primary Control (Stack Switch)

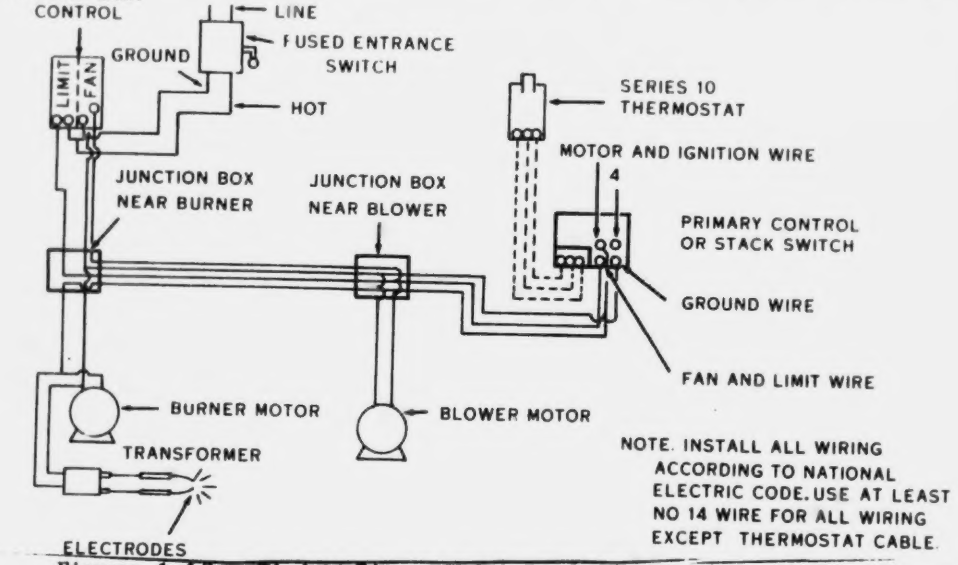

FAN AND LIMIT CONTROL
LIMIT
FAN
GROUND
LINE
FUSED ENTRANCE SWITCH
HOT
SERIES 10 THERMOSTAT
MOTOR AND IGNITION WIRE
4
JUNCTION BOX NEAR BURNER
JUNCTION BOX NEAR BLOWER
PRIMARY CONTROL OR STACK SWITCH
GROUND WIRE
FAN AND LIMIT WIRE
BURNER MOTOR
BLOWER MOTOR
TRANSFORMER
ELECTRODES
NOTE. INSTALL ALL WIRING ACCORDING TO NATIONAL ELECTRIC CODE. USE AT LEAST NO 14 WIRE FOR ALL WIRING EXCEPT THERMOSTAT CABLE.

Figure 1-16. Wiring Diagram for an Oil-Fired Forced Warm-Air Unit

Blower Control (Fan Switch)

The fan switch such as that shown in figure 1-17 controls the operation of the blower motor in a forced warm air heating system.

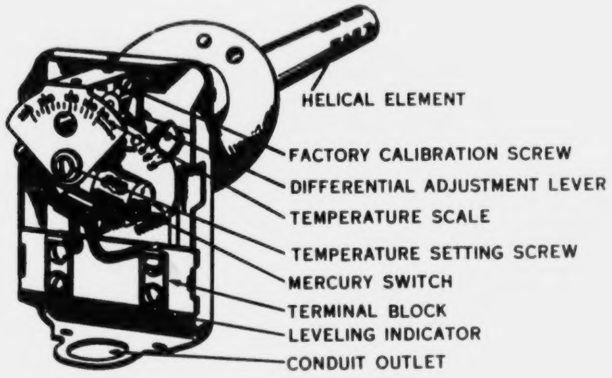

HELICAL ELEMENT
FACTORY CALIBRATION SCREW
DIFFERENTIAL ADJUSTMENT LEVER
TEMPERATURE SCALE
TEMPERATURE SETTING SCREW
MERCURY SWITCH
TERMINAL BLOCK
LEVELING INDICATOR
CONDUIT OUTLET

Figure 1-17.

The temperature actuated fan control makes use of a bimetal strip. This bimetal strip is inserted into the warm air plenum or directly into the air passage of the furnace.

As the temperature of the furnace increases the bimetal strip bends. When the fan's ON setting of the control is reached, usually 15° to 25° above the fan OFF setting, the snap action switch closes and completes the line voltage circuit to the fan motor. Figure 1-18.

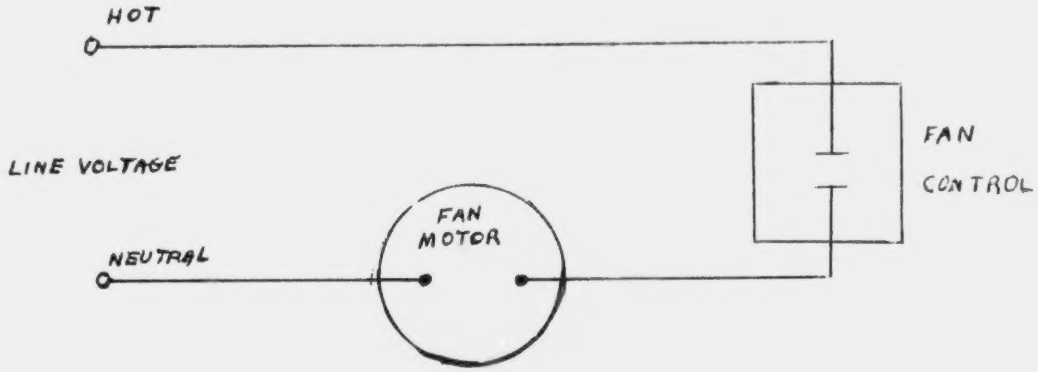

HOT
LINE VOLTAGE
NEUTRAL
FAN MOTOR
FAN CONTROL

Figure 1-18. Schematic of fan motor wiring

When the thermostat is satisfied, or the limit control opens, the main gas valve closes, stopping the flow of gas to the burners. As the furnace cools down, the air delivered through it also cools down and causes the bimetal strip to return to its original position. When this happens the switch is opened and the fan motor stops. The fan off temperature is usually 5° to 10°F above that desired in the heated space.

**Combination Fan Limit Control.** The combination fan and limit control combines the functions of the individual fan and limit controls into a single compact unit. The limit action cannot be set below the fan control action. On some models a summer fan switch is available for the selection of continuous fan operation. Figures 1-19 and 1-20 show a line voltage and a low voltage limit switch.

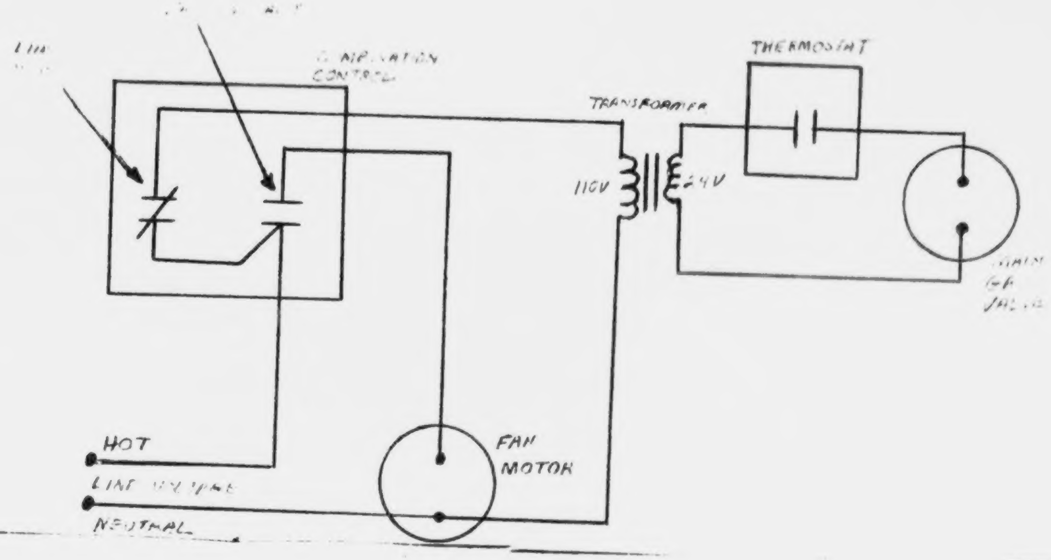

THERMOSTAT
TRANSFORMER
110V
24V
HOT
NEUTRAL
FAN
MOTOR

Figure 1-19. Schematic Showing Line Voltage Limit Switch

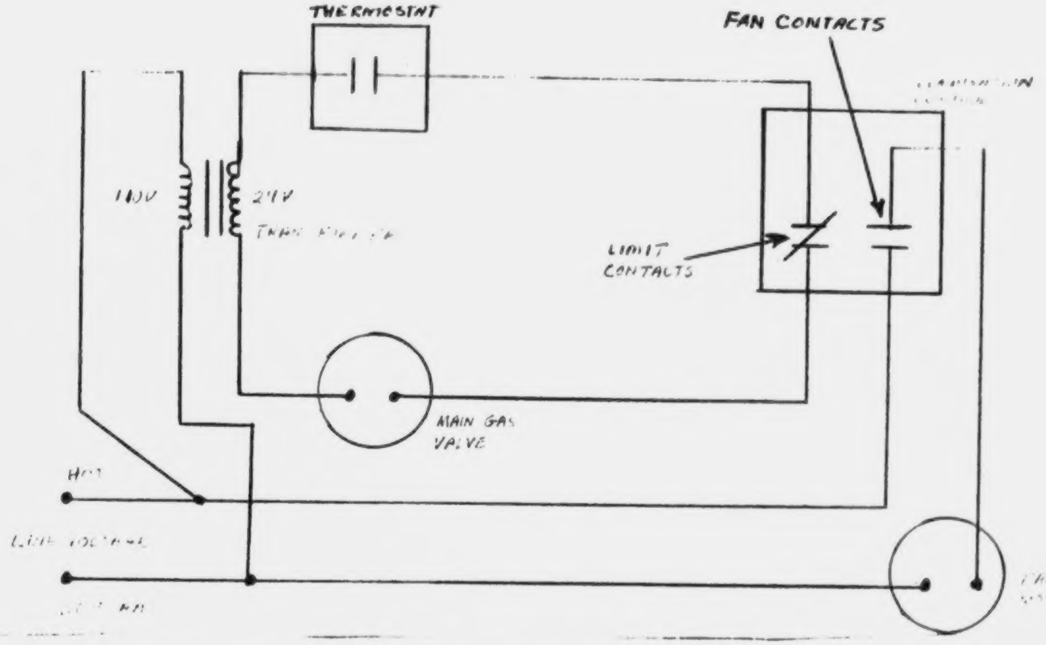

THERMOSTAT
FAN CONTACTS
110V
24V
LIMIT
CONTACTS
MAIN GAS
VALVE
HOT

Figure 1-20. Schematic Showing Low Voltage Limit Switch

## SUMMARY

Electric controls serve a very useful purpose. Without them our job would be much more difficult and require many more people to operate. This in turn would increase the operating costs.

Electric controls will be either two-position or modulating. The difference between the two is in their operation. With a two-position control it will be either off or on. A modulating control can be either off, on, or anywhere in between.

Many automatic controls operate by sensing the temperature around them. These are temperature responsive devices. They make use of bimetallic strips in such shapes as spiral, U-Shape, Q-Shape and helix. Other controls use devices such as a bellows or remote bulb. These are devices which use a volatile liquid that will gasify when heated causing movement of a switch.

One type of electric control that is taken for granted yet used in just about every application is the thermostat. This is a temperature responsive device that controls the heating system. It monitors the temperature of a room, building, etc., 24 hours a day to keep the desired temperature. The only time people take notice of the thermostat is when the room temperature gets too hot, too cold, or when the thermostat goes bad. Remember, the thermostat is a sensitive control, take care of it and it will take care of you.

Some other electric control devices used in heating are safety pilots (pilotstats). These are controls used on a gas system to monitor the pilot flame. Whenever the pilot light goes out the Safety Pilot will shut off the gas to the main burner. There are two types, the thermoelectric which opens the circuit to the gas valve and the valve type that is a valve located in the gasline. It will shut off the gas to both the main burner and the pilot for 100% shutoff.

Another control used on warm air and hot water systems is the limit control. It is a safety device that is located in the burner circuit that will open the circuit if the temperature inside the plenum chamber goes above the preset limits. The proper setting for the limit switch is 175° to 200°F.

Devices that are installed in the system to operate in response to signals received from thermostats are called primary controls. Depending on the type of system you are operating they can be something as simple as a gas valve on a gas fired furnace or the relay in a stack switch used on oil fired equipment.

For a forced warm air system to operate properly you must have a device to control the on off operation of the blower motor. This device is called a fan switch. It is a temperature actuated switch that automatically starts and stops the blower motor by sensing the temperature of the plenum chamber. It should be set to stop the motor when the temperature is 5° to 10°F above that desired in the heated space and set to come on when the temperature gets 15° to 25°F above the off setting.

## QUESTIONS

1. Describe two-position controls.

2. Describe modulating controls.

3. Describe the operation of a bimetal strip.

4. What causes a vapor tension device to operate?

5. What is the purpose of a safety pilot?

6. What is the main difference between the two types of pilotstats?

7. What is the purpose of a limit control?

8. How is the limit control wired in an electrical circuit?

9. What is the primary control for gas?

10. What are the types of automatic gas valves?

11. What is the purpose of the fan switch?

12. How is the fan switch wired in an electrical circuit?

REFERENCE:

AFM 85-12, Vol II, Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization
Modern Refrigeration and Air Conditioning, by Goodheart Wilcox
Electric Controls for Refrigeration and Air Conditioning, By B. C. Langley

## SECTION II

## ELECTRONIC CONTROLS

### OBJECTIVE

To help you understand the purpose and use of electronic controls used in heating systems.

### INTRODUCTION

Operation of today's modern equipment requires the use of controls that are much more sensitive and accurate than the basic electric controls. Electronic controls fulfill these requirements.

### INFORMATION

### Purpose and Use of Electronic Controls

### PURPOSE

As man's need for more accurate control of heating increased so did his need for more sensitive controls.

In today's heating systems we are more concerned about safety than ever before. For example, if a large boiler that was burning oil suddenly lost its fire, how could you tell? If you were not there to see, this oil could still flow into this hot unit. This then creates a very unsafe condition where an explosion could occur.

### USE

In heating we use electronic controls for flame safeguard protection in both furnaces and boilers.

Since a furnace does not run continuously it does not get as hot or produce as manyl exhaust gases as a large boiler. Flame safeguard protection consists of a device that "watches" the flame and will open the burner circuit if a flame failure occurs.

In a large boiler it is not as simple as in a furnace. Since large "central" boilers run continuously they get exceptionally hot and produce large quantities of gases. To shut this unit down with a hot combustion chamber and all these gases could produce a very hazardous condition. Shutdown of a large boiler must be done in stages. First, the fuel must be shut off, then allow the blowers to remove the gases and then finally shut down the entire unit. These are called programmers.

### Types of Electronic Flame Safeguard Devices

PROTECTO-RELAY. The protecto-relay is an electronic flame safeguard control tha automatically controls the operation of both the pilot and burner. If either fails t light the protecto-relay will shut down the entire unit until the unsafe condition is corrected. Before you can restart it you must first reset it.

PROGRAMMER. The programmer is an electronic flame safeguard control that provides ignition and flame failure protection for industrial automatically ignited oil and gas burners. They work with the limit, operating controls and automatically program the operation of the burner or blower motor, ignition and main fuel valves.

The programmer automatically shuts the unit down when there is a power failure or a flame failure. After flame failure you must manually reset it before the unit can be restarted.

### Electronic Flame Safeguard Sensors

Electronic sensors are used in flame safeguard devices to "sense" the presence of combustion. These sensors may respond to visible or invisible light or the flame itself.

**FLAME ROD.** The flame rod was the first electronic flame sensor. The flame rod allows the conduction of electricity through a flame to complete a circuit. If the flame fails there is no longer a continuous path for current to flow, see figure 1-21.

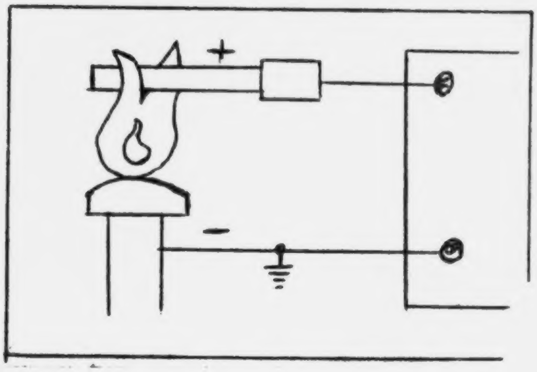


Figure 1-21. Flame Rod

RECTIFYING PHOTOCELL. The rectifying photocell changes AC/DC when exposed to visible light. See figure 1-22.

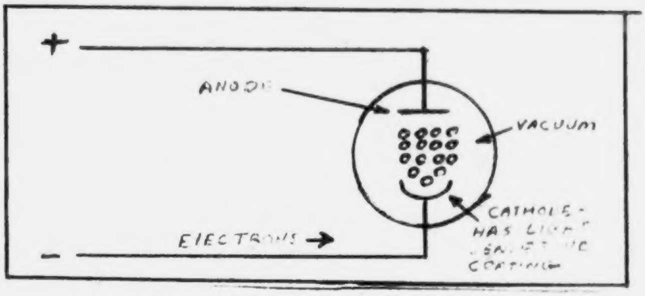

+
ANODE
VACUUM
CATHODE - HAS LIGHT SENSITIVE COATING
ELECTRONS →
−

Figure 1-22. Rectifying Photocell

CADMIUM CELL. The cadmium cell sensor has the ability to change resistance when exposed to visible light. See figure 1-23.

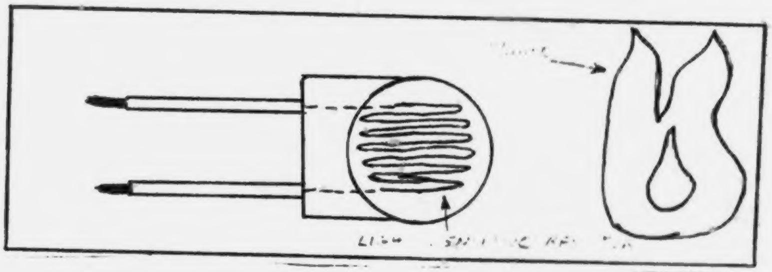

FLAME
LIGHT SENSITIVE RESISTOR

Figure 1-23. Cadmium Cell

**LEAD SULFIDE.** Lead sulfide cell is an electronic sensor that senses infrared light. See figure 1-24. The electrical resistance of lead sulfide drops when exposed to infrared radiation. If a voltage is applied across the lead sulfide in the cell, current will flow when the cell is exposed to infrared radiation.

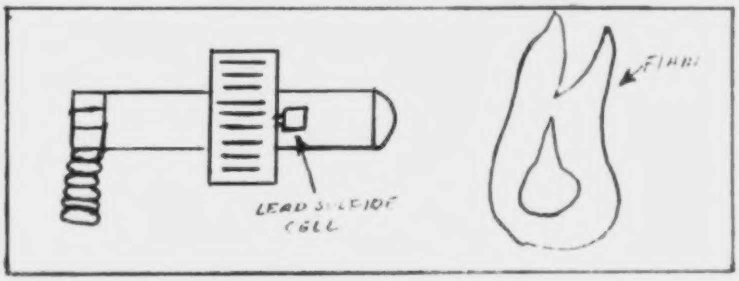


Figure 1-24. Lead Sulfide

ULTRAVIOLET SENSOR (Purple Peeper). The ultraviolet sensor is an electronic sensor that senses ultraviolet light. See figure 1-24. When a high enough voltage is applied across the electrodes, and the tube is exposed to an ultraviolet source, the cathode emits electrons, which ionize the gas in the tube. When the gas fill is ionized, the tube becomes conductive and current flows through the tube.

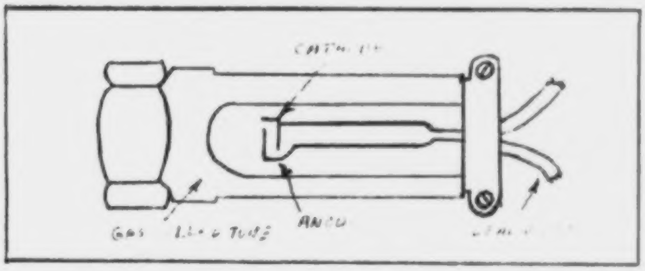


Figure 1-25. Ultraviolet Sensor

## SUMMARY

Fire produces both visible and invisible light. Electronic sensors are devices that respond to the visible or invisible light produced by flame.

We use electronic flame safeguard devices such as protecto-relays and programmers to make use of these sensors.

Each sensor serves a specific purpose. From the flame rod which allows for the conduction of electricity through a flame to the ultraviolet detector which senses ultraviolet light. We must assure the safety of everyone. This is accomplished by watching out that the fuel supply will be shut off moments later. This eliminates a possibly dangerous situation.

QUESTIONS

1. What is meant by the term "flame safeguard"?

2. Why must a large "central" boiler use a programmer as an electronic flame safeguard?

3. What was the first electronic flame sensor?

4. What are electronic sensors?

REFERENCE

Flame Safeguard Controls by Honeywell, First Edition

# SECTION III

# PNEUMATIC CONTROL SYSTEMS

## OBJECTIVE

To help you identify procedures for maintaining pneumatic control systems.

## INTRODUCTION

One of the greatest problems in heating is the control of the heating effects. Automatic controls are used to solve this problem by sensing and controlling the amount of heat.

An automatic control system must have some type of energy for operation. Pneumatic controls use compressed air for operation as electric and electronic controls use electricity for operation. This study guide pertains only to pneumatic controls.

A working knowledge of the operating theory and definition of terms, common to pneumatic controls, is essential for you to operate and adjust pneumatic controls.

You will see that a control can perform more accurately than a human being. You will agree that we have a need for automatic controls. If you think of controlled devices (valves, dampers, louvers, etc.) as being slaves and the controllers (thermostats, humidistats, etc.) as being masters, you will understand the function of pneumatic controls.

## INFORMATION

### Pneumatic Control Fundamentals

Heating systems are fast becoming an automated factory in which the product is the manufacture of heat. Controls dominate the process; therefore, it is necessary that you understand the theory of controls and their application, so that these controls can operate at peak efficiency.

### Purpose of Pneumatic Controls

The main purpose of pneumatic controls is to automatically maintain a predetermined condition in schools, office buildings, hospitals and various places occupied by people and equipment.

Figure 1-26 shows a heating system that is controlled manually. When the temperature gets low, the person sees that the thermometer is lowered in degrees, so he opens the steam valve. The temperature rises, which causes the thermometer to indicate a higher temperature. The person will close the valve to lower the temperature. So, the temperature is controlled by regulating the amount of heating in the conditioned space.

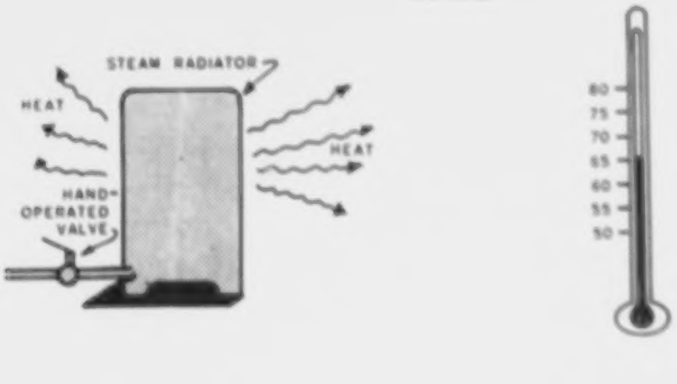


Figure 1-26. Manual Control of Temperature

Since this system requires constant attention, we desire a system that will automatically regulate the temperature.

Pneumatic controls are needed when we desire to automatically control temperature, relative humidity, pressure, level, flow and various other conditions.

Air Compressor

The air compressor plays a very important part in pneumatic control systems. Figure 1-27 shows a typical tank-mounted compressor. A correctly sized compressor should not run more than 50 percent of the time to maintain operating pressure. A thermal overload protect is usually built into the electrical circuit to prevent damage to the system in event the compressor drive motor becomes overloaded.

The air compressor (see figure 1-27) has a suction intake filter to clean the air that goes into the compressor. The compressor pushes the air into the storage tank until the pressure control stops the electric motor that is turning the compressor. When the pressure goes down, the pressure control turns the motor on again. The air leaves the compressor and goes through a filter and on to the pressure-reducing valve which reduces the high pressure to 15 to 20 psig as required by manufacturer.

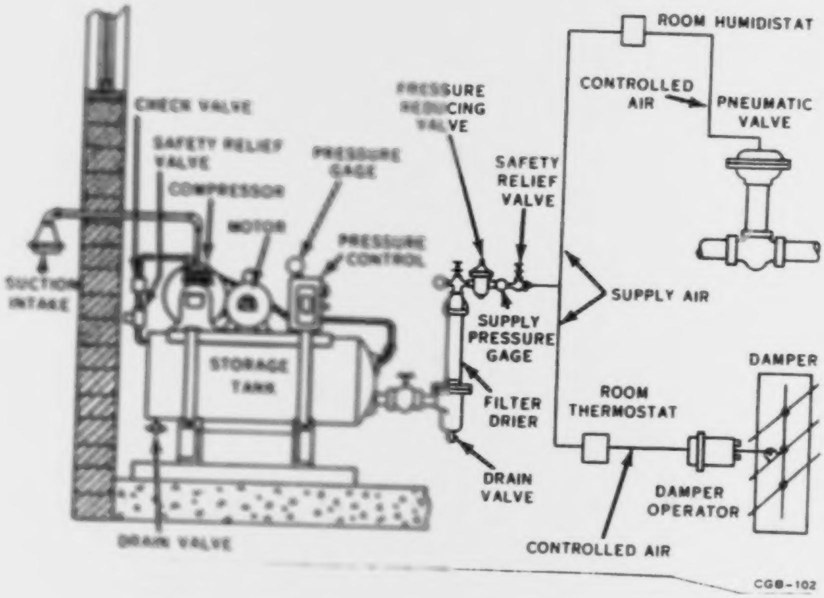

CHECK VALVE
SAFETY RELIEF VALVE
COMPRESSOR
MOTOR
PRESSURE GAGE
PRESSURE CONTROL
SUCTION INTAKE
STORAGE TANK
DRAIN VALVE
PRESSURE REDUCING VALVE
SAFETY RELIEF VALVE
SUPPLY PRESSURE GAGE
FILTER DRIER
DRAIN VALVE
ROOM HUMIDISTAT
CONTROLLED AIR
PNEUMATIC VALVE
SUPPLY AIR
ROOM THERMOSTAT
DAMPER
DAMPER OPERATOR
CONTROLLED AIR
CGB-102

Figure 1-27. Pneumatic Control System

SERVICING AIR COMPRESSORS. Servicing points of an air compressor are shown in figure 1-28. A description of what should be done at each point is as follows:

Figure 1-28. Compressor Servicing Points

- Lubrication (1). Keep oil at proper level. Use SAE-10 cylinder oil. Drain and refill crankcase after first two weeks of operation, and thereafter every two or three months.

- Storage Tank (2). Accumulated dirt, oil and water must be eliminated periodically. Blow off tank through petcock or drain plug at bottom at least once a day.

- Air Filter (3). If equipped with petcock at bottom, drain when draining tank. Inspect excelsior packing after two years of service and every year thereafter. Replace it when it shows signs of becoming saturated with oil. Clean or renew felt pads when dirty.

- Suction Filter (4). Clean suction filter every six months, or oftener when atmosphere is especially dirty.

- Motor (5). Oil every three months or as recommended on motor nameplate, if motor does not have permanently lubricated bearings.

- V-Belt (6). Adjust tension after first month of operation. Check every six months thereafter. Avoid excessive belt tightness, which overloads bearings. Correctly adjusted belt permits an inch or so of flexing between pulleys.

- Valves (7). Remove and clean intake and exhaust valve once each year. If leakage exists after cleaning, causing inefficient compresser operation, replace with new valves.

- Pop Safety Valves (8). Blow off pop valves every six months to insure against sticking.

- Reducing Valve (9). Check adjustment periodically. They should be set to maintain the correct system pressure at all times.

## Air Piping and Distribution System

Air piping and distribution systems for pneumatic controls consist of supply air lines and control air lines. These lines could be pipe (black iron or galvanized), or tubing (copper or plastic). The size of this pipe or tubing may vary from 1/8" to 2" in diameter.

SUPPLY AIR LINES. This line distributes the flow of air from the pressure regulating valve to the controller. The minimum air pressure in this line must be 15 psig and is maintained at a constant pressure.

CONTROL AIR LINES. This line distributes the flow of air from the controller to the controlled device. The air pressure in this line may vary from 0 to 15 or 20 psig. The air pressure varies because of the type controller action (direct or reverse acting) and the controller response (two position and proportional).

Most air piping and distribution for pneumatic controls are concealed within the building structure, and except for possible damage due to building alterations, requires no servicing. Piping in equipment, boiler rooms and pipe shafts are often run exposed. These exposed lines are usually run in out-of-the-way places, with properly arranged supports and hangars. Care should be exercised so that these lines do not become damaged.

## Closed and Open Loops

All automatic control systems have a common pattern which recognizes the relationship of "cause and effect"; that is, the interdependence of one thing upon another. This is commonly called "feedback". Feedback makes true automatic control or self-regulation possible. The following examples clarify this point.

In figure 1-29 the room thermostat (TR) measures the temperature of the air surrounding it. As the temperature rises, the thermostat causes a reduction of the heat input (HI) to the room, which allows the room temperature (RT) to stop rising or to drop. This, in turn, affects the thermostat, which readjusts its influence on heat input until a balance is stabilized. Thus, one change is dependent upon another and a "closed loop system" has been established.

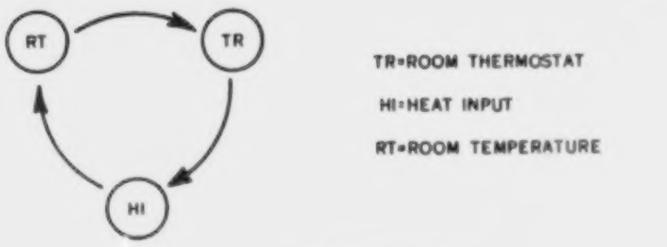


Figure 1-29. Closed Loop System

There are three basic parts which must be considered when putting together a closed loop system. They are:

THE CONTROL AGENT. This source of energy supplied to the system can be either hot or cold, such as steam, hot water, heated air, chilled water or chilled air.

THE CONTROLLED DEVICE. A valve or damper, either Normally Open or Normally Closed to regulate the flow of the Control Agent.

THE CONTROLLER ACTION. A controller is furnished with either Direct Action or Reverse Action. This will allow the balance mentioned above.

The proper combination of these three parts must be applied or the Closed Loop System will not operate.

In the open loop system, for example, when heat is required to maintain a suitable room temperature as the outdoor temperature drops. It is possible to arrange a thermostat to measure outdoor temperature and cause the heat input of a building to increase as the outdoor temperature decreases. The outdoor thermostat cannot measure the result of heat input to the room, hence there is no feedback. (See figure 1-30)

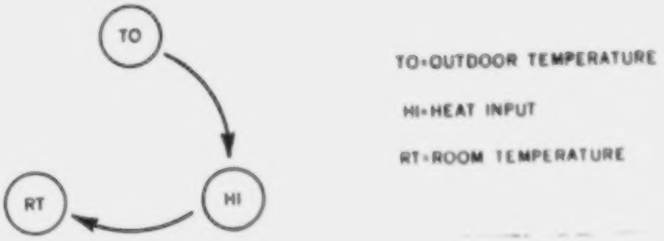


Figure 1-30. Open Loop System

It should be clear that all control systems are comprised of one or more loops. Most of them will be closed loops, but some may be open loops. It is necessary to understand the difference in order to appreciate what results can be expected. When controllers are studied, it will be seen that they comprise one or more control loops within themselves.

It should be pointed out that there are no perfect closed loops, that is, loops which must account only for the effect of the parts as described. In actual control conditions, outside forces constantly work on the various parts to change the balance and set the loop cycle in operation to reestablish a balance. If this were not the case, there would be no need for automated control.

In summary, it can be said that a "closed loop system" is one in which all parts have an effect on the next step in the loop, and are affected by action of the previous step. An "open loop system" is one in which one or more of the steps has no direct effect or action imposed on the following step, or is not affected by other steps in the loop.

### Pneumatic Controllers

A pneumatic controller is an instrument that measures variations in temperature, humidity or pressure and changes its output pressure or control pressure accordingly.

Controllers are classified as either direct or reverse acting. A direct acting controller increases its control pressure with an increase in temperature, humidity or pressure (controlled variable), and a reverse acting controller decreases its control pressure with an increase in the controller variable.

In order for the control system to function properly, each controller must react in a specified manner. Controllers are furnished for two types of action.

TWO POSITION (POSITIVE) ACTION. The control pressure is either at a maximum or minimum with no intermediate steps. This type of controller produces "on-off" control with the controlled device in either of two positions -- open or closed.

PROPORTIONAL (GRADUAL) ACTION. The control pressure varies in proportion to the change in the controlled variable. This type of controller produces a gradual action of the controlled device, with the controlled device positioned to any intermediate position between fully open and fully closed.

### Two-Position Pneumatic Closed Loop System

A two-position controller is an instrument that provides a full output signal, or no output signal, with no intermediate steps. It is also known as an "on-off" or snap controller.

The controlled device can be a valve or damper operator which will be either fully open or fully closed, depending on the signal from the two-position controller. A spring in all controlled devices is under tension at all times and will return the controlled device to its normal position when the controller's signal is removed.

Figure 1-31 shows a closed loop system with a two position controller. The thermostat (controller) measures the room temperature and opens the valve (controlled device) when the temperature falls to a lower limit on the differential. This admits steam to the radiator, which in turn heats the air in the room. Then, the room temperature rises, providing feedback to the thermostat, which closes the valve when the temperature reaches the top limit of differential.

### Proportional Pneumatic Closed Loop System

A proportional controller is an instrument that produces an output signal in direct proportion to a change in input (controller variable). The output signal of a proportional pneumatic controller can vary from 0 psig to the maximum pressure supplied to the system. Most controllers can be adjusted to vary their output pressure for a given change in the controlled variable. This is referred to as "sensitivity."

The controlled device, such as a valve, receives the output signal from the controller and is thereby positioned in proportion to the signal.

A proportional controller is capable of producing any output pressure between 0 psig and the maximum pressure supplied to it.

### Sensitivity

The output signal change from the controller (controller action) will be in proportion to the change in the controlled variable. If the controller changes its output signal one psig when the controlled variable (temperature) changes one degree Fahrenheit, the controller is said to have a sensitivity of one psig per degree. In most controllers the sensitivity is adjustable so that the output signal (psig) change can be made more per degree or less per degree, to give better control.

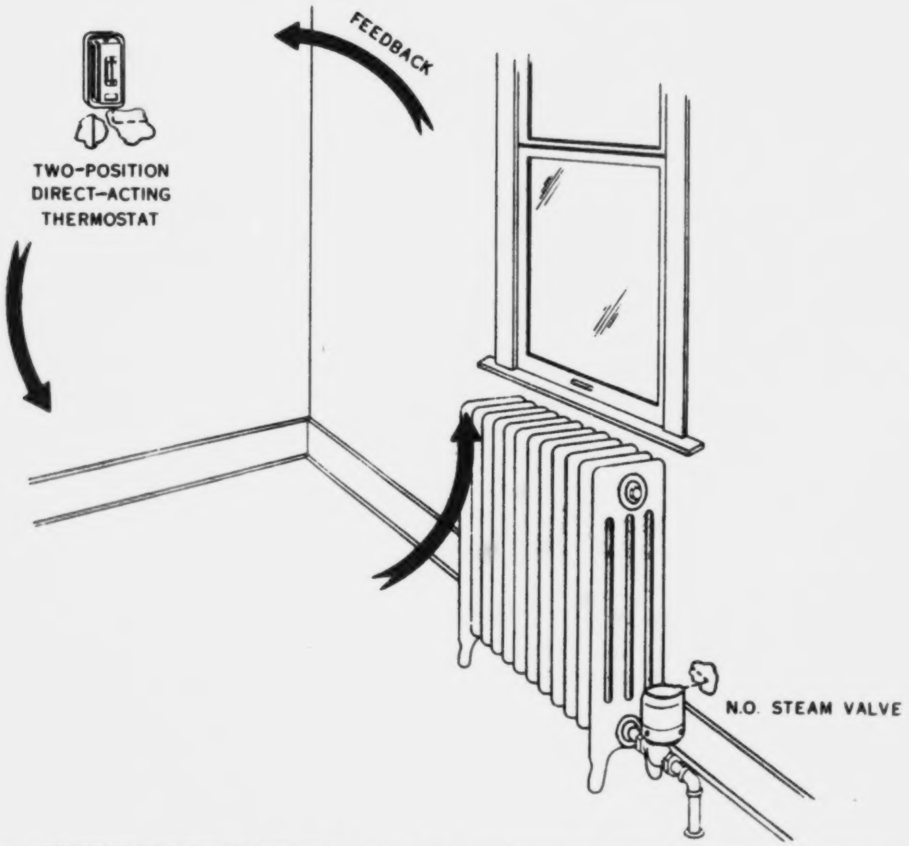


Figure 1-31. Typical Closed Loop System with Two-Position Controller

### Load Changes

Outside temperature, heat output from people, lights and machinery in the controlled space are referred to as load changes. In other words, they are mediums affecting the space or room conditions.

### Pneumatic Controlled Devices

The controlled device is the final control element that is activated by the control pressure. The controller, as you have seen, senses the measured variable and regulates control pressure to the controlled device. The controlled device regulates the flow of control agent, such as chilled water, hot water, steam, hot air and cold air, to maintain the controlled variable.

## SUMMARY

Heating systems are fast becoming an automated factory in which the product is the production of conditioned air. Controls dominate the process; therefore, it is necessary that you understand the theory of controls and their application, so that these controls can operate at peak efficiency.

The controlled device is the final piece of equipment in a control system that regulated the controlled variable in accordance with the demands of the controller. The device is usually a valve controlling the flow of fluid in a line or a damper operator controlling the flow of air in a duct.

Pneumatic controllers must be sensitive to changes in the controlled variable and respond with a precise output signal of adjustable magnitude to prevent the controlled variable from deviating too much from set point. A controller has two main parts: the measuring or sensing element, and the body (relay) which produces the output signal.

QUESTIONS

1. How many different types of control system loops are there? What are they?

2. What determines the pressure in the air supply tank?

3. What determines the pressure in the supply line?

4. What determines the pressure of the control air?

5. Where does the air first enter the sytem?

REFERENCE

Johnson Field Training Handbook, Fundamentals of Pneumatic Control
by Johnson Controls
Johnson Service Company Appartus and Service Bulletins

# TROUBLESHOOTING OF ELECTRICAL CONTROLS

## OBJECTIVE

1. Using step-by-step procedures, troubleshoot electrical controls on a warm air furnace trainer with instructor assistance.

2. Trace electrical circuits, isolate electrical malfunctions, and perform minor repairs to electrical circuits.

## INTRODUCTION

Trouble with a heating unit often involves electrical problems. The heating specialist should be able to troubleshoot electrical circuits. He can simplify his work by determining if the malfunction is electrical or mechanical. Troubleshooting can be defined as a "systematic method of locating faults in an electrical circuit."

## INFORMATION

### Types of Troubles

An important fact to remember is that there are only three types of electrical troubles: opens, shorts and low power.

### Opens

An open circuit is one that has a break somewhere in it. This break could be located in the wire, in the switch, fuse, or in the unit of resistance. If there is a break, there can be no current flow and the unit of resistance would not be operating (see figure 2-1).

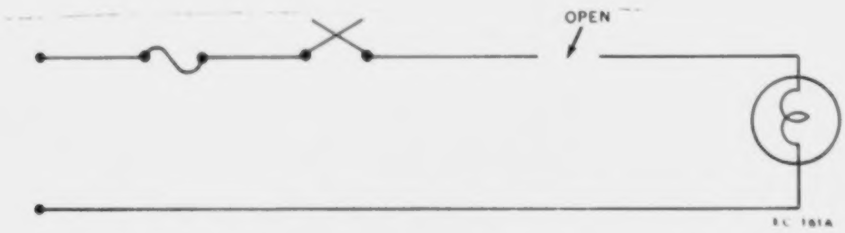


Figure 2-1. Open Wire

Now, consider some examples of opens. In figure 2-2 the battery shown has a loose connection. Most of the time, a loose connection is the same as no connection, which is the same as an open circuit. Any circuit component with a loose connection opens the circuit, which naturally stops the current. Another type of trouble that will cause an open is a burned out component.

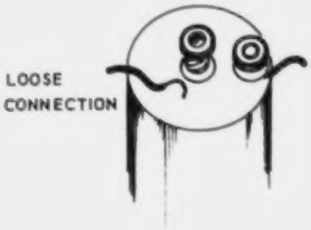


Figure 2-2.

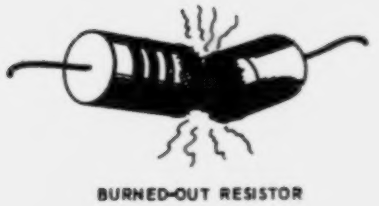


Figure 2-3

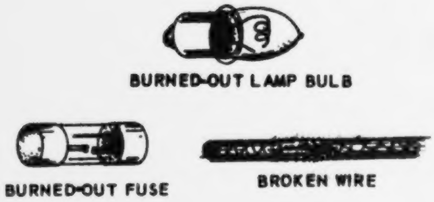


Figure 2-4

Figure 2-3 shows a burned out resistor. When a resistor becomes overheated, one of two things will happen--the resistor's ohmic value will change or the resistor will completely burn apart due to the excessive current flowing through it.

Figure 2-4 shows three more likely causes for an open circuit: a burned out lamp bulb, a burned out fuse, and a broken wire. All of these are examples of an open, and they all give the same result--no current flow.

Shorts

A short means that there is contact where there should not be contact. Consequently, there is current flow where there should not be current flow. Indications of shorts are units operating that should not be operating, blown fuses or tripped circuit breakers.

DIRECT SHORT. In the case of a direct short, a negative lead is in contact with a positive lead, bypassing the unit of resistance. From figure 2-5, you can see that current in this situation will take the path of least resistance. The excessive current flow will cause the fuse to blow or if the protective device is a circuit breaker it will trip, opening the circuit.

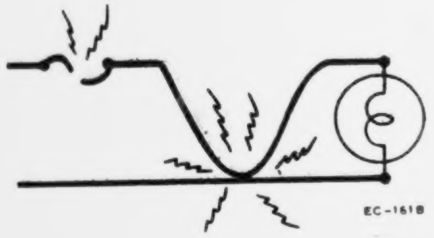


Figure 2-5. Direct Short

You have seen how an open stops current flow. Shorts produce just the opposite effect. A short across a component produces a larger than normal current flow. Some examples of shorts are two bare wires in a circuit touching each other, connecting the two terminals of a resistor together, connecting the two terminals of a battery together, or improper wiring. Some examples are shown in figure 2-6.

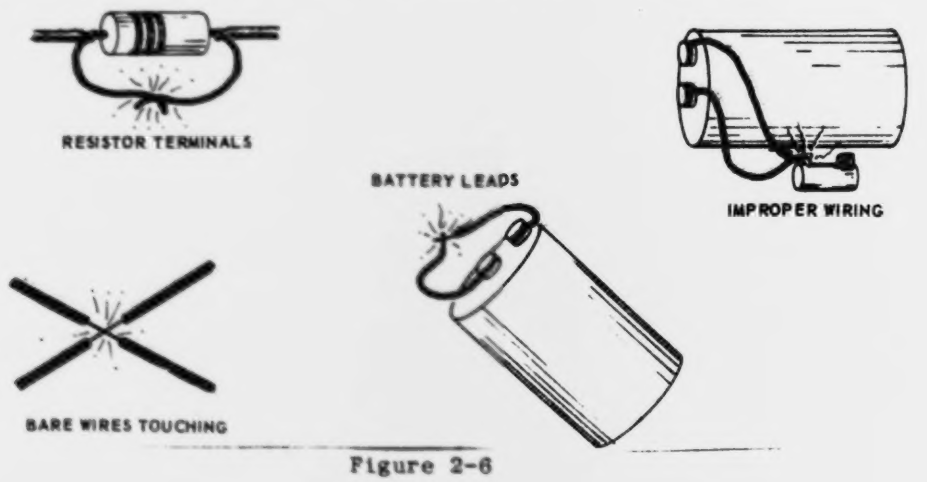


Figure 2-6

Since you know that a short is a connection of two conductors of a circuit through a very low resistance, let's consider the circuit shown in figure 2-7. This circuit is designed to light a lamp. Since the resistance of the lamp is normally low, a resistor is connected in series with it to control the amount of current flowing through the lamp. If the resistor is shorted out, total circuit resistance would decrease, and the current would increase. This increase in current would cause the lamp to become much brighter. If the battery voltage were high enough, the increased current could destroy the lamp. However, since we have a circuit protective device (fuse) in the circuit, the fuse should open before the lamp is damaged. The fuse is designed to open the circuit before the current exceeds the maximum current rating of the circuit.

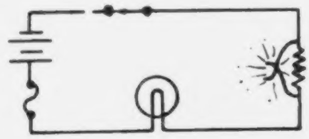


Figure 2-7

CROSS SHORTS. A cross short is caused by the hot leads of independent circuits coming in contact with each other.

During an operational check, a cross short is indicated by two independent units operating from the same switch. In figure 2-8, positive lead A-8 is touching positive lead A-3. Even through the switch which controls $L_2$ is open, there is a complete path for current flow from A-8 to A-1; consequently, $L_2$ burns.

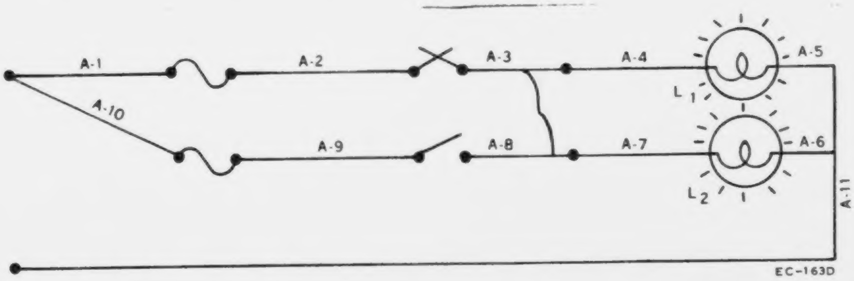


Figure 2-8. Cross Short

Low Power

This condition is often found in old buildings or in areas where the electrical load has been increased without increasing the size or number of electrical circuits. A low power condition is indicated by sluggish operation of units and dim lights.

## Isolation of Troubles

Different procedures are used to troubleshoot the various types of troubles.

Opens

There are four different testers that can be used to find an open. These are the voltmeter, continuity tester, ohmmeter and test light.

The exact location of an open can be found by using the voltmeter. You should, first of all, understand what a voltmeter indicates in a normal operating circuit. Figure 2-9 illustrates normal voltmeter readings throughout the circuit.

A voltmeter connected positive-to-negative should always indicate the difference in potential across the two points. A voltmeter connected negative-to-negative or positive-to-positive should not give a difference in potential. (See figure 2-9) Readings other than these are considered abnormal. Exact location of an open can be found in the positive or negative parts of the circuit between a normal and an abnormal reading.

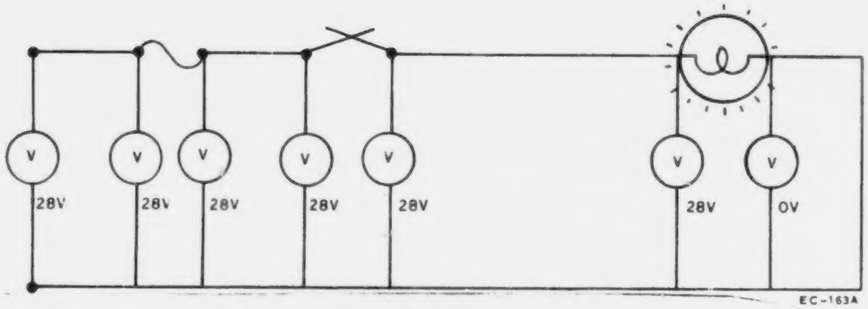


Figure 2-9. Normal Voltmeter Readings

In figure 2-10, a voltmeter is being used to locate an open in the circuit. The exact location is wire A-6.

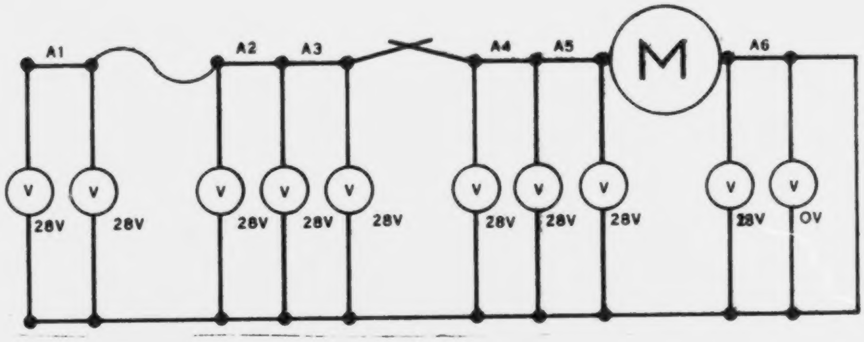


Figure 2-10. Locating an Open in Wire A-6

The same procedure is used in troubleshooting an open with a test light; however, a test light will not give an indication of the amount of voltage present. All you know is that there was enough current available to light the lamp.

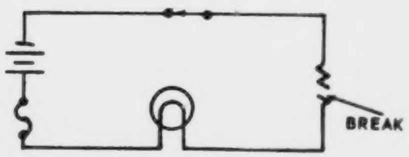


Figure 2-11.

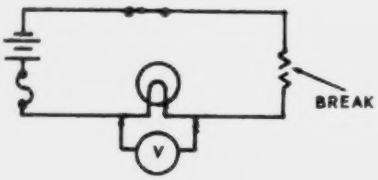


Figure 2-12.

The circuit in figure 2-11 is used to light a lamp; but, because of the open resistor, the lamp will not light. Suppose the resistor appears to be all right upon visual inspection. How can you tell it is open? You can do this with either a voltmeter or an ohmmeter.

Connecting the voltmeter across the lamp as shown in figure 2-12, a reading of 0 volts will be indicated on the meter. The reason for the zero reading is the open resistor, which will not allow current to flow through the circuit. With no current flowing through the lamp, no voltage will be dropped across the lamp.

Connecting the voltmeter across the resistor as shown in figure 2-13, current will flow from the negative terminal of the battery back to the positive terminal of the battery and the voltmeter will indicate the applied voltage.

So, we have another good point to remember. When the voltmeter is placed across the open component in a circuit, it will indicate the applied voltage.

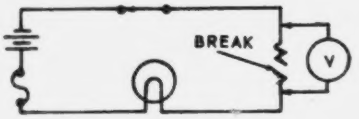


Figure 2-13.

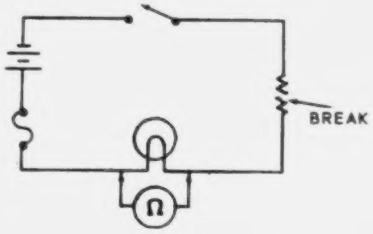


Figure 2-14.

We said previously that we could check the circuit to find the open component with an ohmmeter. Let's see how we would accomplish this. Since we are going to use the ohmmeter, we know that the applied voltage will not be needed to make our check. We will open the circuit by opening the switch. Then we will connect the ohmmeter across the lamp as shown in figure 2-14.

With the ohmmeter connected across the lamp, it will indicate the resistance of the lamp. A good point to remember; when you connect an ohmmeter across a good component, the ohmmeter will indicate the resistance of that component and it also shows that we have continuity.

Opens can also be found by using an ohmmeter or a continuity meter. Power must be off and the circuit isolated when using continuity testers. In figure 2-15, an ohmmeter is being used to locate an open in wire A-6.

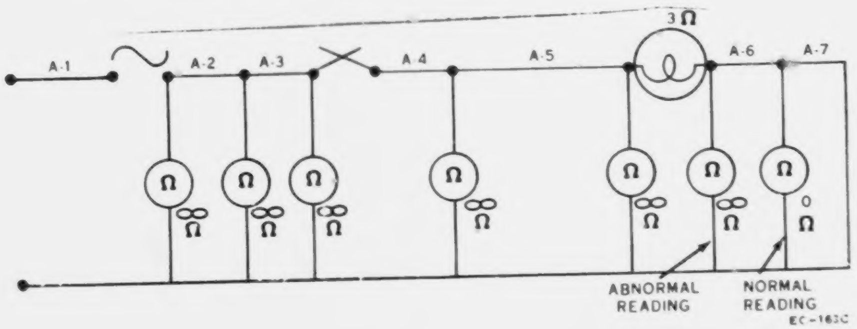
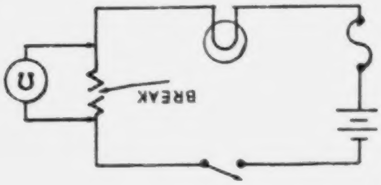


Figure 2-15. Locating an Open with an Ohmmeter



With the ohmmeter connected across the resistor, as shown in figure 2-16, it will indicate infinite resistance, or no continuity. So remember, when you connect the ohmmeter across an open component, the ohmmeter will indicate -- infinite resistance.

By now you should have a clear understanding of what an open is, and how to find opens in a circuit.

Figure 2-16.

## Shorts

There are two types of shorts.

**LOCATING DIRECT SHORTS.** Some kind of continuity tester, such as the ohmmeter, continuity meter or continuity light is used in locating direct shorts. The negative leads should be isolated and the testing device connected across the isolated leads. Notice in figure 2-17, an ohmmeter is being used to locate a direct short. Only the ohmmeter connected to the A-4 lead indicates continuity (0 ), therefore, A-4 lead is shorted to the opposite side of the circuit providing a shortcut for current flow.

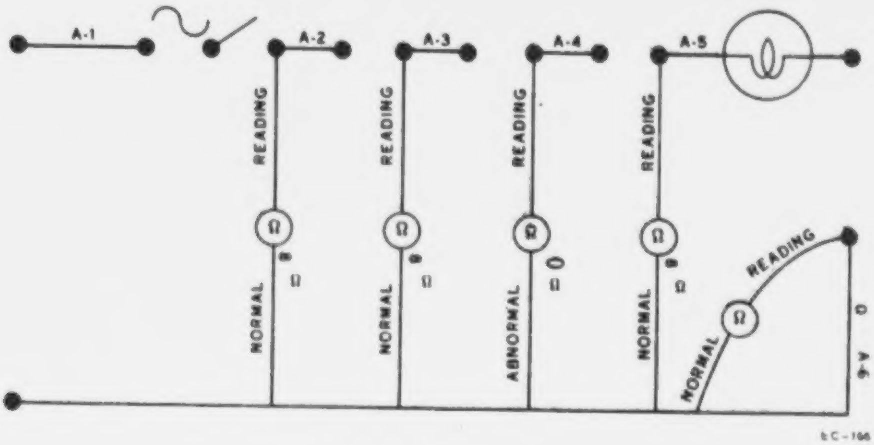


Figure 2-17

When troubleshooting circuits, remember open circuits have no current flow and shorted circuits have too much current flow.

**LOCATING CROSS SHORTS.** The same testing devices and procedures are used in locating cross shorts as were used in locating direct shorts. Power must be off and the positive leads of both circuits isolated. (See figure 2-18)

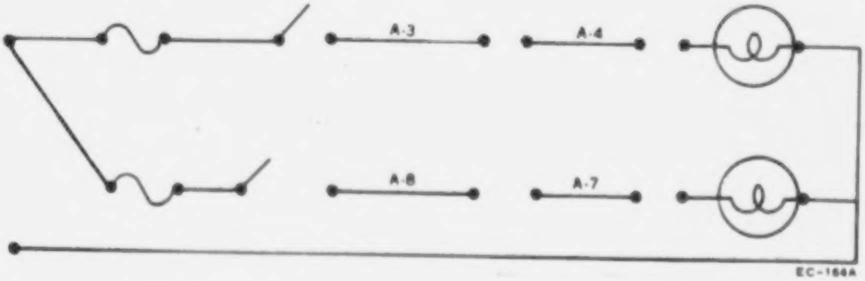


Figure 2-18. Probable Leads Isolated

After both circuits are isolated, the testing device is connected across the probable leads, such as A-3 to A-7, A-3 to A-8, A-4 to A-8, or A-4 to A-7. Note that any of these combinations would have the same effect. In figure 2-19, the ohmmeter shows the cross short to be between A-3 and A-8.

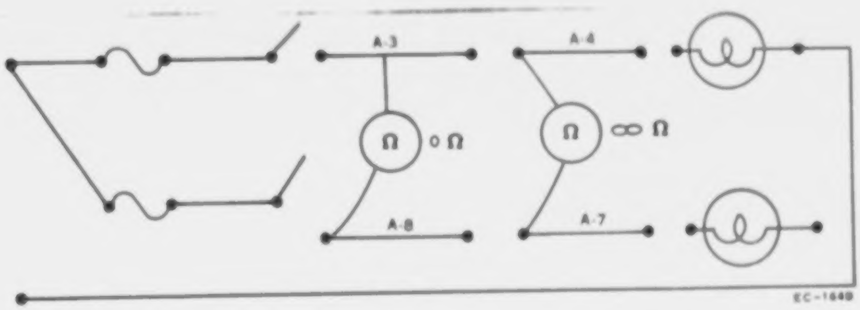


Figure 2-19. Locating a Cross Short

A shorted switch is one that fails to break contact when it is placed in the off position. The effect of a shorted switch is that the unit operates continually. In figure 2-20 an ohmmeter indicates the switch is shorted.

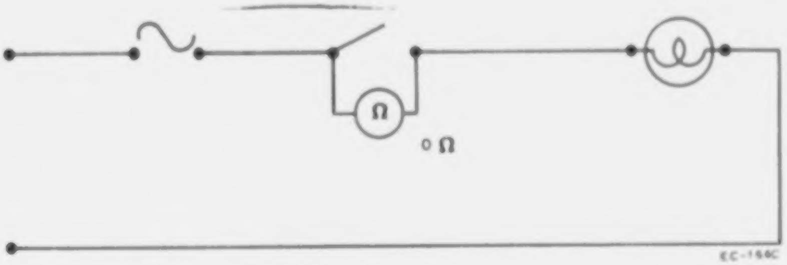


Figure 2-20. Checking for a Shorted Switch

Low Power

If a low-power condition is suspected, all electrical units on the circuit should be turned on. This should create maximum current flow. Voltage drops across the units should be compared with total voltage. Figure 2-21 shows a line loss check.

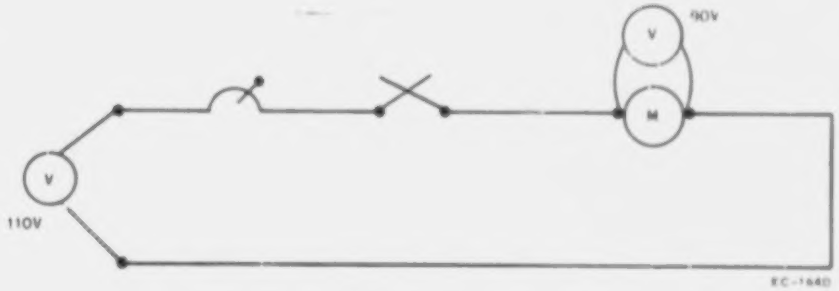


Figure 2-21. Voltage Drops Should Equal Total Voltage

If a low power condition is discovered, the electrical load must be reduced or a new circuit installed.

SUMMARY

Troubleshooting is a systematic means of locating malfunctions in a circuit.

The three types of troubles are: opens, shorts and low power.

Opens prevent the flow of current, whereas a short allows it to flow where it is not wanted. Low power causes sluggish operation of units.

The testing devices are the voltmeter, continuity meter, ohmmeter and test light.

Continuity devices must be used in circuits where the power is off and the circuit isolated. Voltmeter and test light are used in circuits where the power is left on.

QUESTIONS

1. What testing device cannot be used in locating a cross short?

2. What is the indication of a direct short?

3. What is one cause of low power?

4. What testing devices are used in circuits where power can be left on?

5. How is the circuit checked for low power?

6. What is the effect of an open circuit?

7. What is a shorted switch?

REFERENCE

Modern Refrigeration and Air Conditioning by Goodard Wilcox

# COMBUSTION EFFICIENCY AND DRAFT

## OBJECTIVE

Upon completion of this lesson, you will be able to:

1. Perform combustion analysis and compute combustion efficiency.
2. Explain procedures necessary to adjust stack draft to assure proper combustion.

## INTRODUCTION

Combustion of any fuel produces waste. When the fuel is coal, oil, gas, wood or other organic compounds, the waste produced takes various forms of carbon and other bothersome residue. And, that causes a problem: what to do with the end products of combustion. There was a time when concern over that problem was small and the answer was easy, simply release the smoke or other waste into the atmosphere. Today, the answer is not so easy. In recent years we all have begun to be concerned about the products of combustion that hover, pregnant with death--not life--over our cities.

Since smoke causes air pollution, it is often a public nuisance and is usually restricted by public ordinances. When associated with fog it produces "smog" which may be detrimental to aircraft components, electronic and other sensitive equipment. Also, it may constitute a flight hazard. Soot deposits on boiler heating surfaces cause the following:

--Reduction of boiler capacity because of the insulating effects on the heat transfer surfaces.

--Increase of draft loss because of the increased restriction to gas flow.

--Increase of corrosion because of the sulfur compounds generally found in soot.

--Increase of boiler outlet gas temperature, and decrease of boiler efficiency because of the decreased heat transfer.

## INFORMATION

### PERFORM COMBUSTION ANALYSIS

Combustion efficiency is the ratio of the useful heat delivered by the burning fuel to the supply of fuel. The most efficient combustion is that which releases the greatest amount of "usable" heat from fuel. Usable heat is that heat which is available for heating the boiler or furnace.

To really understand how combustion efficiency is measured, you must consider the chemistry of combustion. All fuels consist largely of carbon. The air we breathe consists of 20 percent oxygen. (The remaining air is nitrogen, with small amounts of other gases.) When burning takes place, the oxygen in the air combines with the carbon in the fuel to release a gas called carbon dioxide ($CO_2$). Each particle of $CO_2$ gas is made up of one carbon atom and two oxygen atoms. The "C" in the formula stands for one carbon atom; and the "$O_2$" stands for two oxygen atoms.

In this burning process, two atoms of oxygen always unite with one atom of carbon. In other words, it takes a definite amount of oxygen to burn a given amount of carbon. The efficiency of combustion can be checked by instruments.

Only the oxygen of the air supports combustion. In perfect combustion, the entire 20 percent of oxygen from the air combines with carbon atoms to produce a corresponding 20 percent of carbon dioxide. By measuring the carbon dioxide of the flue gases, you can determine how efficiently the fuel burns.

When the fire receives too little air, one atom of oxygen combines with one atom of carbon to release carbon monoxide (CO). Unlike carbon dioxide, carbon monoxide is highly poisonous. Breathing very small amounts of carbon monoxide can be fatal.

You might think that all that has to be done to attain maximum combustion efficiency is to supply the fuel with more air than it actually needs (since air is free, anyhow) to make sure there are enough oxygen atoms to combine with the carbon atoms. However, the excess air carries much of the heat directly up the smokestack. This is as inefficient as not providing enough air.

The desirable percentage of carbon dioxide in flue gases varies with the kind of fuel. Experiments have shown that a coal is most efficient when the flue gas contains about 12 percent carbon dioxide. For fuel oil, the content should be about 10 percent, and for gas about 8 percent. Several methods are used to determine the combustion efficiency of a boiler. Some $CO_2$ analyzers, such as the portable units, are quite simple to operate, whereas the automatic recording types are very complex.

The $CO_2$ analysis readings can be used with reasonable accuracy as guides to combustion conditions. If combustion is proceeding properly, the chances for incomplete combustion are slight. Water vapor does not show up in the $CO_2$ analysis because it has been condensed in the process.

NOTE: The key to proper combustion is the three T's (time, temperature and turbulence).

TURBULENCE. Fuel cannot burn completely if the combustible elements are not provided with an adequate quantity of oxygen. Also, the air must be intimately mixed with the combustible elements of the fuel so that all fuel particles are in contact with the required oxygen. This condition is usually brought about by supplying the air in a manner that produces a high degree of turbulence.

TEMPERATURE. Combustion is possible only when the combustible elements of the fuel reach a minimum ignition temperature in the presence of oxygen. When this temperature is reached, combustion occurs and more heat is produced by the combustion reaction than is lost to the surroundings. Combustion then becomes self-sustaining.

TIME. The combustible elements of a fuel must be allowed sufficient time to burn. If the reacting materials are carried to a low temperature zone before combustion reactors are finished, incomplete combustion will result even when the furnace temperature is correct for ignition, the supply of oxygen adequate, and the mixing proper.

The methods of combustion analysis are the comparison method and the absorption method. Although there are numerous analyzers, these two methods are the ones used to determine combustion efficiency.

### Orsat Flue Gas Analyzer (Figure 3-1)

Since it is humanly impossible for an operator to actually see the gases of combustion in a boiler, he cannot know his actual combustion efficiency. He cannot feel exhaust gases and ascertain their degree of heat; he cannot perceive the amount of steam being produced, for steam is an invisible gas. Therefore, it might be well for the operator to look to instrumentation as an extension of his own senses. Actually, they are the windows through which he can see and control what is taking place in his boiler plants. Without them, he could only guess and in most instances his guesses would be entirely wrong or come too late to be of any use.

The Orsat flue gas analyzer is designed to determine the percentage of $CO_2$ (carbon dioxide), O (oxygen), and CO (carbon monoxide) present in the flue gas leaving the boiler. It is an absorption-type unit comprised essentially of the major components listed below.

Water jacketed burette graduated in centimeters, a leveling bottle and three-way cock. The three items are used to measure a specified amount of flue gas through the chemicals used to determine percentage of $CO_2$, O, and CO.

The second major component consists of the pipettes (three each) used to hold the chemicals as follows:

-- Cardisorber or $CO_2$ absorber.

-- Pyrogallic Acid or O absorber.

-- Cuprous Chloride or CO absorber.

The third major component consists of the aspirator bulb, filter and sampling tube. These three items combined provided a means of obtaining a representative sample from the flue and forcing the gas through each respective chemical.

Operating Principle. This instrument operates on the volumetric measurement and chemical absorption in the same manner as the installed absorption $CO_2$ analyzer. The advantage with this instrument is the fact that it is portable and has the capability to measure amounts of carbon dioxide ($CO_2$), carbon monoxide (CO), and oxygen (O) with one flue gas sample by following established procedures. Figure 3-1 illustrates the Orsat and its basic components.

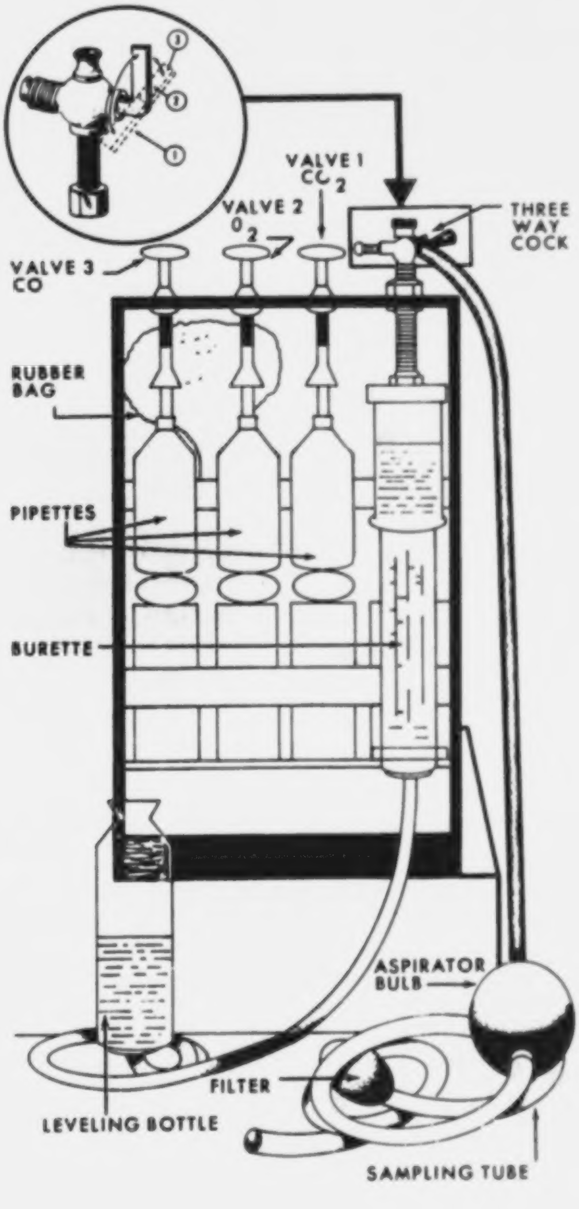
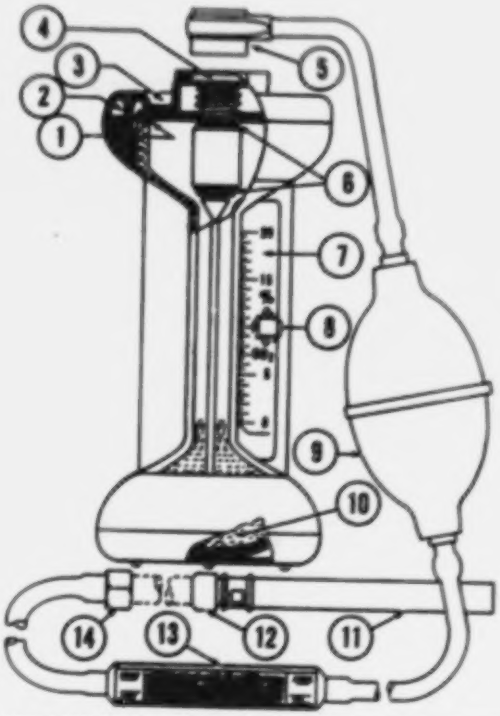

③
②
①
VALVE 1
$CO_2$
VALVE 2
$O_2$
THREE WAY COCK
VALVE 3
CO
RUBBER BAG
PIPETTES
BURETTE
ASPIRATOR BULB
FILTER
LEVELING BOTTLE
SAMPLING TUBE

Figure 3-1. Orsat Flue Gas Analyzer

### Fyrite $CO_2$ Analyzer and Components

The Fyrite $CO_2$ analyzer is an absorption type analyzer designed to measure the efficiency of combustion by measuring the percentage of $CO_2$ present in the flue gas. Figure 3-2 illustrates the tester and its components.



1. Gasket
2. Top Cap Holding Screw
3. Top Cap
4. Plunger Cap
5. Connector Tip
6. Plunger Seats
7. $CO_2$ Scale
8. Scale Locking Screw
9. Rubber Aspirator Bulb
10. Bottom of Analyzer
11. Filter Nipple
12. Connection Sampling Tube to Filter Nipple
13. Filter Tube
14. Connection Tubing to Sampling Tube

Figure 3-2. Typical Fyrite $CO_2$ Analyzer

To insure accurate, reliable results, inspect the Fyrite analyzer for proper fluid level, proper fluid strength, and proper operation of sampling assembly.

Four basic steps are necessary in making an analysis for the percentage of $CO_2$ with the Fyrite:

--Adjust zero percent scale mark to the top of fluid column.

--Pump sample to be analyzed into Fyrite.

--Absorb $CO_2$ from sample into Fyrite fluid.

--Read percent of $CO_2$ on scale at the top of fluid.

### Fixed Flue Gas Analyzer

Continuous gas analyzers are more satisfactory for long-term analysis results. Their major purpose is to give an accurate continuous indication of combustion conditions within the combustion chamber. It can be expected that no control will hold the air-fuel ratio constant after once being set, since fuel characteristics, as well as boiler conditions, will change as time passes. Only through occasional readjustments of the controls, as indicated by results of gas analysis, can peak combustion efficiency be maintained. Since most continuous analyzers are calibrated with portable analyzers, it is important that the function of both types be understood.

Since each manufacturer incorporates different features of design in his particular instruments, it would be impossible to describe them all in the time allocated. Normally, the manufacturers will supply full technical data with their products. For this lesson, we will limit our discussion to the following main topics:

-- Condu-Therm Analyzer

-- Absorption Type Analyzer

CONDU-THERM ANALYZER. The fact that gases and vapors conduct heat at various rates provides thermal conductivity as a means of gas analysis. For analysis, the sample must be a binary mixture of the gas to be measured and a background gas.

The background gas may be a single gas or it can be composed of several gases acting as one.

If the mixture consists of a measured gas and one other gas (a binary mixture), the net thermal conductivity varies as the percentage of the measured gas varies.

The receiver is calibrated to show the desired measurement in percentage. The sensitivity depends on the amount of difference between the thermal conductivity of the two gases.

The thermal conductivity of a mixture of gases, including the gas to be measured, is compared with that of a background or reference gas. The difference between the thermal conductivity of the sample and reference gases is used as a measurement of the percentage of one gas in a mixture of gases.

In order to use this method of measurement, the difference in thermal conductivity must vary proportionally with the concentration of the gas to be measured.

The Condu-Therm analyzers provide two types of analyses. One is used to measure the concentration of a gas whose thermal conductivity is greater than that of the reference gas.

The other type is used to measure a gas whose thermal conductivity, is less than that of the reference gas. The difference between the two is an electrical modification which causes the pen to read upscale.

Sample gas diffusing into the measuring cell absorbs heat from the measuring resistor in a direct ratio to the thermal conductivity of the sample gas. Thus, any difference in the themal conductivity of the two gases (sample and reference) changes the voltage balance of a Wheatstone bridge circuit in the system schematic (figure 3-3). Any voltage unbalance of this circuit is transmitted to an amplifier. Here, this voltage unbalance is amplified and impressed on the pen drive motor windings. This motor operates a slide wire to rebalance the bridge circuit. A cam, also rotated by the motor, operates the indicator and/or pen to show the net thermal conductivity directly as a percent by volume measurement of the sample gas.

The measurement of $CO_2$ in flue gas is a common application of the Condu-Therm analyzer. In this application, the thermal conductivity of flue gases is compared with that of a reference gas (usually air).

Normally, flue gas is a mixture of nitrogen (N), oxygen (O), sulfur dioxide ($SO_2$), carbon dioxide ($CO_2$) and water vapor. The N (and other inert gases in air) percentage of thermal conductivity remains constant.

The gas sample is saturated with water vapor as it enters the cell block, and the percentage of water vapor is thus held constant. The $SO_2$ percentage is very small and for all practical purposes it can be considered to be $CO_2$. Therefore, O and $CO_2$ are the chief variables in the sample gas, and the percentage of one increases as the other decreases, in a definite relationship. The thermal conductivity of the flue gas mixture changes as the percentage of $CO_2$ changes. The receiver is calibrated to show the percentage of $CO_2$ in the gas mixture.

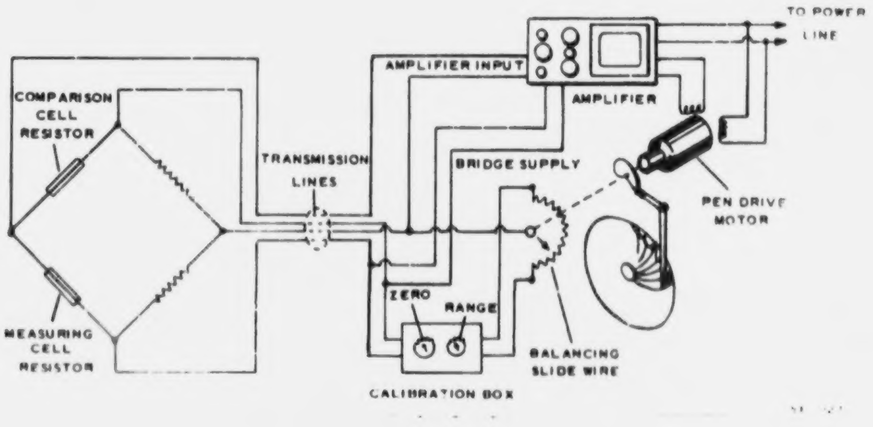

TO POWER
LINE
AMPLIFIER INPUT
AMPLIFIER
COMPARISON
CELL
RESISTOR
TRANSMISSION
LINES
BRIDGE SUPPLY
PEN DRIVE
MOTOR
ZERO
RANGE
MEASURING
CELL
RESISTOR
BALANCING
SLIDE WIRE
CALIBRATION BOX

Figure 3-3. System Schematic

Operation of Analyzer. Two electrically self-heated, identical, glass covered resistors are mounted in separate chambers in the analyzing cell block (figure 3-4). These resistors form two legs of a Wheatstone bridge circuit.

Since these resistors have large temperature coefficients, any difference in temperature between them results in an electrical output signal proportional to the temperature difference.

A reference gas whose thermal conductivity is known diffuses into the reference chamber where small changes of temperature and pressure in the reference gas are compensated for by a heated reference resistor. This provides a standard against which the measuring cell resistor is compared.

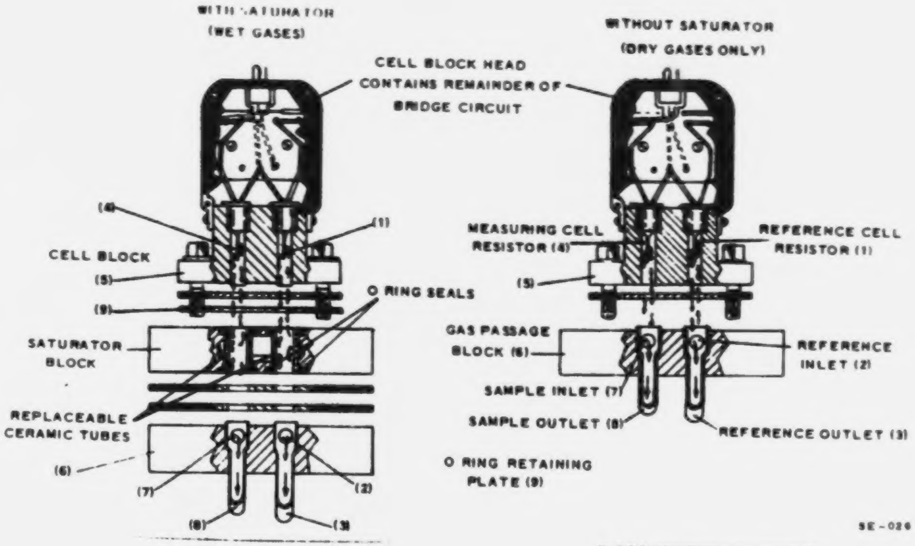

WITH SATURATOR
(WET GASES)
WITHOUT SATURATOR
(DRY GASES ONLY)
CELL BLOCK HEAD
CONTAINS REMAINDER OF
BRIDGE CIRCUIT
(4)
(1)
CELL BLOCK
(5)
(9)
O RING SEALS
SATURATOR
BLOCK
REPLACEABLE
CERAMIC TUBES
(6)
(7)
(2)
(8)
(3)
MEASURING CELL
RESISTOR (4)
REFERENCE CELL
RESISTOR (1)
(5)
GAS PASSAGE
BLOCK (6)
REFERENCE
INLET (2)
SAMPLE INLET (7)
SAMPLE OUTLET (8)
REFERENCE OUTLET (3)
O RING RETAINING
PLATE (9)
SE-026

Figure 3-4. Analyzing Cell Block

ABSORPTION $CO_2$ ANALYZER. Another type of installed $CO_2$ analyzer used commonly throughout Air Force bases is the absorption unit which analyzes $CO_2$ samples approximately every two minutes. Only the operating principle will be covered in this study guide.

Operating Principle. This instrument operates on the principle of volumetric measurement and chemical absorption. A sample of flue gas is automatically measured at a constant pressure. It is then directed into an absorption burette where the $CO_2$ content of the sample comes in contact with an absorbing chemical, $CO_2$ absorber (cardisorber). In absorbing the $CO_2$, liquid cardisorber is displaced in an inverse proportion to the $CO_2$ content of the sample gas. The $CO_2$ content is then recorded on a chart at the end of each analysis.

## Computing Combustion Efficiency

The Combustion Efficiency Graphs in the workbook may be used to determine the combustion efficiency when burning the more common fuels. When using these graphs, it is necessary to know: first, the percentage of the $CO_2$ in the flue gas; second, the temperature of the flue gas; third, the room temperature; and fourth, the type of fuel being used. With this information, determine the combustion efficiency in the following manner:

--Find the difference between the flue gas temperature and room temperature. This is the net stack temperature.

--Locate, on the bottom of the scale, the point that represents the net stack temperature on the proper graph.

--Find the diagonal line which represents the amount of carbon dioxide in the flue gas.

--Find the point of interception of the two lines.

--Draw a horizontal line to the left-hand scale from where the two lines intercept. The point at which the horizontal line crosses the left-hand scale represents the percentage of combustion efficiency.

The procedures for adjusting the fuel-air ratio must be done safely. These procedures will vary with the type of equipment installed.

## Maintenance of Flue Gas Analyzers

When performing maintenance of flue gas analyzers, follow manufacturer's procedures and observe all safety precautions.

## SUMMARY

To have a heating plant operate efficiently requires that the operator have all the "know-how" regarding all of his equipment. The best test equipment available is only as good as the person or persons using it. Therefore, it is up to the individual to familiarize himself with the test instruments that he will be using.

The Condu-Therm gas analyzer operates on the principle of thermal conductivity. Any difference in thermal conductivity of two gases causes a temperature difference, changing the resistance, and consequently, the voltage balance of the Wheatstone bridge circuit. The resultant output voltage is transmitted to the recorder where it is detected, amplified and impressed on the pen-drive motor.

The absorption $CO_2$ meters operate on the Orsat principle of volumetric measurement and chemical absorption. A gas sample of flue gas is pulled by a venturi, tested, and $CO_2$ content is recorded on a chart approximately every two minutes.

## QUESTIONS

1. What is meant by the term "combustion efficiency?"

2. Soot is caused by

3. What is meant by the term "perfect combustion?"

4. What type of gas indicates good combustion?

5. What is the minimum percent $CO_2$ for oil?

6. What information must be known to be able to compute combustion efficiency?

## REFERENCES

1. AFM 85-12, Volume I, Operation and Maintenance of Central Heating Plants and Distribution Systems.
2. Hays Corporation Bulletin No. 55-E621.
3. Bacharach Instrument Company Pamphlet 10-OP-51.

# DOMESTIC AND INDUSTRIAL OIL BURNERS

## OBJECTIVE

Upon completion of this lesson, you will be able to:

1. Explain characteristics of oil, theory of gravity and forced fuel oil sypply system.
2. Install, operate and maintain rotary pumps.
3. Inspect and maintain fuel oil piping systems.
4. Perform preoperational checks and operate, adjust, maintain, troubleshoot and replace oil furnaces.

## INTRODUCTION

The Air Force uses many different types of oil burners. In this study guide we will cover the different types of fuel burning equipment. It will be done in two sections.

SECTION I -- Fuels and Fuel Systems

SECTION II -- Domestic and Industrial Oil Burners

## SECTION I

## FUELS AND FUEL SYSTEMS

### OBJECTIVE

To help you in learning the types of oil used in heating installations, including handling, piping systems and the pumps used to move this oil.

### INTRODUCTION

Many trees, ferns and other types of vegetation have grown, died, decayed and been covered with layers of the solid particles that form the earth's surface. Geologists believe that the decomposition of these minute marine growths or possibly of vegetable matter in some cases formed the oil which lies trapped in pools between layers of the earth's crust. This crude oil consists of complicated combinations of carbon and hydrogen called hydrocarbons.

### INFORMATION

#### Characteristics of Oil

Fuel oils are derived from crude petroleum. This crude petroleum is a mixture of hydrocarbons and small amounts of nitrogen, sulfur, and vanadium; the amount of each substance present varies with petroleum source. The various products derived from petroleum, including fuel oils, are separated by fractional distillation. This is a process by which liquids with different boiling points are separated from solution by repeatedly evaporating and condensing portions of the mixture. See figure 4-1. In general, fuel oils can be divided into two major classifications; distillate and residual.

Distillate Fuel Oils. When the fractional distillation process is applied to crude petroleum, the gaseous and light substances boil off first, followed by the gasoline, the kerosene, and then the light and heavy distillate fuel oils ("gas oils").

Residual Fuel Oils. When marketed as a fuel, the "bottom" or residual material from the distillation process is called residual fuel oil. Since crude petroleums from various sources differ widely in composition, there is considerable difference in these oils. In general, they are heavy, dark and not as fluid as the lighter distillate oils.

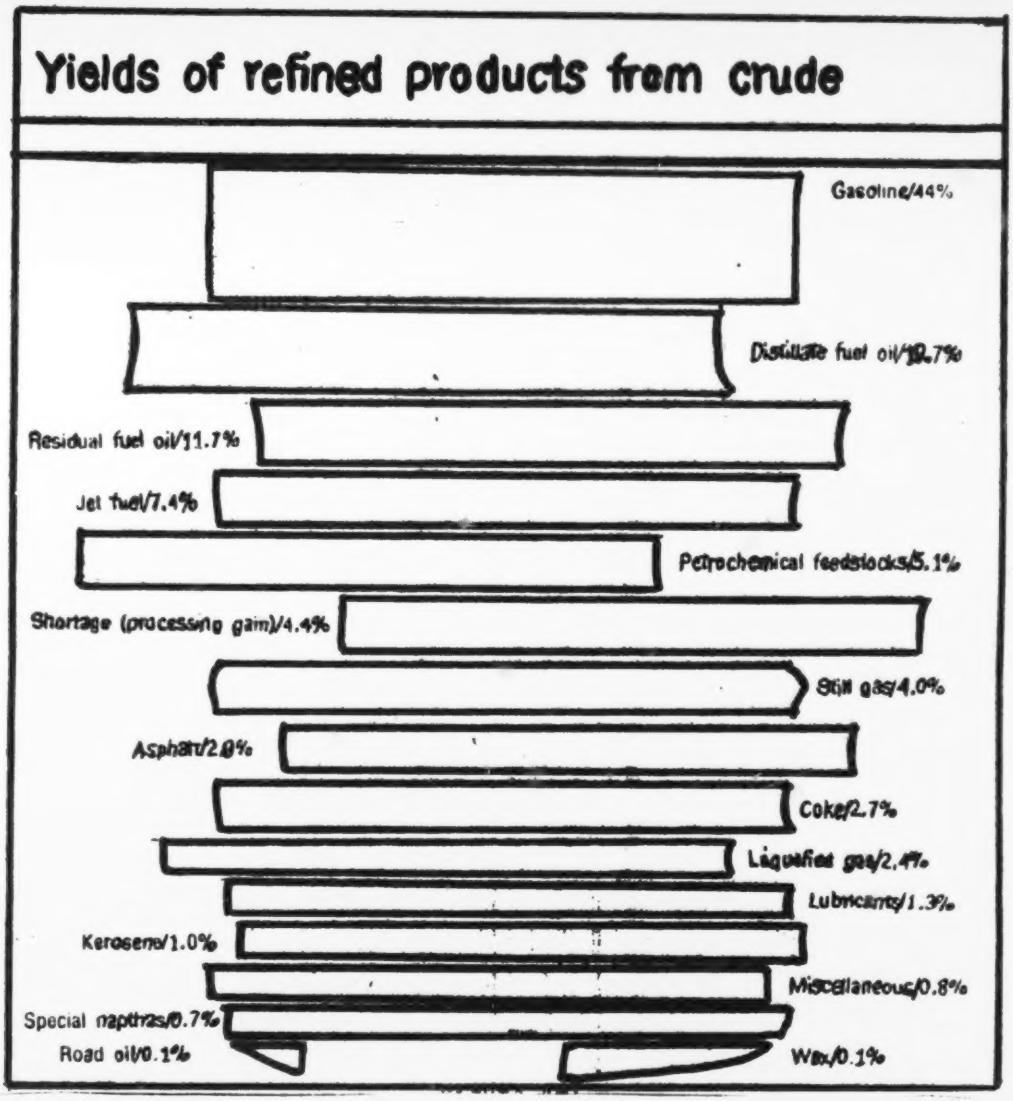


Figure 4-1

Commercial Grade Fuel Oils. Commercial-grade fuel oils are generally classified according to physical characteristics and use. These oils are intended for use in various types of fuel-burning equipment under various climatic and operating conditions, for the generation of heat in furnaces for heating buildings, for the generation of steam, or for other purposes. The grades covered by this specification are intended for specific applications as indicated below:

Grade No. 1. A light distillate oil intended for use in burners of the vaporizing type in which the oil is converted to a vapor by contact with a heated surface or by radiation. The average BTU content for No. 1 is 136,000 BTU's per gallon.

Grade No. 2. A heavier distillate than grade No. 1. It is intended for use in atomizing-type burners which spray the oil into a combustion chamber where the tiny droplets burn while in suspension. This grade of oil is used in most domestic burners and in many medium-capacity commercial-industrial burners where its ease of handling and ready availability sometimes justify its higher cost over the residual grades. The average BTU content of No. 2 is 138,500 BTU's per gallon.

Grade No. 4. Usually a light residual but sometimes a heavy distillate. It is intended for use in burners equipped with devices that atomize oils of higher viscosity than domestic burners can handle. Its permissible viscosity range allows it to be pumped and atomized at relatively low storage temperatures. Thus, except in extremely cold weather, it requires no preheating for handling. The average BTU content for No. 4 is 145,000 BTU's per gallon.

Grade No. 5. A residual fuel of intermediate viscosity for burners capable of handling fuel more viscous than grade No. 4 without preheating. Preheating may be necessary in some types of equipment for burning and in colder climates for handling. The average BTU content of No. 5 is 148,500 BTU's per gallon.

Grade No. 6. A high-viscosity oil, sometimes referred to as "Bunker C," and used mostly in commercial and industrial heating. It requires preheating in the storage tank to permit pumping and additional preheating at the burner to permit atomizing. The extra equipment and maintenance required to handle this fuel usually preclude its use in small installations. The average BTU content for No. 6 is 152,000 BTU's per gallon.

Properties and Characteristics. The most important properties of burner fuel oils are viscosity, flash point, and water and sediment.

VISCOSITY. The relative ease or difficulty with which an oil flows is called viscosity. Viscosity indicates how oils will behave when pumped and shows when preheating is required and what temperature must be maintained. A low viscosity allows the fuel to flow readily through supply lines and to be broken up by atomizing type burners.

FLASH POINT. Flash point represents the temperature at which an oil will give off enough vapor to make a flammable mixture with air.

WATER AND SEDIMENT. Water and sediments are impurities and while it is not economical to eliminate them they should not occur in large quantities. This normally is not a problem with the distillate fuels. However, residual fuel will usually contain a measurable amount of one or both due to the nature of the product and conditions of storage. Any measurable amount of sediment results in strainer blockage, fouling of burner tips, lines, etc., and may cause soot deposits.

## THEORY OF GRAVITY AND FORCED FUEL OIL SUPPLY SYSTEMS

The Air Force stores fuel to have available at all times a reasonable supply in accordance with the requirements of the installation equipment, and to provide an emergency supply for use in case of interruption of the normal delivery schedule.

Among the units of a fuel oil supply system are storage tanks, piping systems, pumps, values and strainers.

FUEL OIL STORAGE TANKS. Oil storage tanks can be of either the above-ground or below-ground type.

Aboveground Storage Tanks. Aboveground storage tanks are usually cylindrical and constructed of steel. they may be either horizontal or vertical. Electrical grounding of aboveground steel storage tanks is required to safely discharge static electricity, which may build up an electrical potential on the tank. Grounding is important, since it prevents fires and explosions which could be caused by sparks discharged by static electrical charges.

Below-ground Storage Tanks. Underground fuel oil storage tanks are usually of the all-welded steel type, with a suitable exterior protective coating. A reinforced concrete slab is generally used as the tank foundation. The steel bottom of the tank is securely anchored to the foundation slab at frequent intervals to prevent failure of lifting due to water pressure between the slab and the steel tank bottom. The extent of this anchoring should be adequate to meet the groundwater condition where the tank is located. Underground tanks have the same type of auxiliary equipment as above ground storage tanks. Under certain soil conditions, corrosion of below-ground steel storage tanks may occur. This corrosion is generally associated with a flow of electric current away from the metal. To prevent this, cathodic protection is often used. Cathodic protection consists basically of a suitable electrical potential applied to the tank to make it cathodic (negative) to the surrounding soil. This produces a current flow to the corroding metal and reduces corrosion to a minimum.

COMPONENTS OF FUEL OIL STORAGE TANKS. The component parts used with fuel oil storage tanks are:

Fill Pipe. Filler pipes for steel fuel oil storage tanks should be large to permit rapid filling. For safety, they should be at least two feet away from the building openings on the same or lower levels.

Vent Pipe. Vent pipes are sized for the desired rate of filling. They extend higher than the filler opening and are equipped with a water-proof head and screen. No connections are permitted from them to any other pipe. Vent openings are located as far as possible from buildings and sources of ignition.

Other components used with fuel oil storage tanks are level indicators (liquidometers), supply piping from the tank to the heating unit, and return piping from the heating unit to the tank. Manholes may also be installed on fuel oil storage tanks for easy access for cleaning; also, ground straps or cables are used in grounding above-ground tanks.

Fuel Oil Storage Tanks. An empty fuel oil storage tank should never be entered by personnel without permission and instructions from the proper authority. It is seldom necessary to clean a fuel oil tank until the sludge becomes excessive, the interior of the tank becomes excessively corroded, or the tank has to be repaired. When fuel oil tanks are cleaned, certain safety precautions must be complied with and certain methods followed. Personnel engaged in cleaning fuel tanks will be completely informed of the danger involved and the need for strict observance of all safety rules. Explosion and fire, the presence of toxic liquids, vapors, or dusts, excess fuel vapors and oxygen deficiency, and physical hazards are the principal dangers of tank cleaning operations.

Three conditions must exist to cause fire or explosion: fuel vapors, oxygen, and source of ignition. While it is almost impossible to eleminate the first two conditions, particularly at the start of a tank cleaning job, the third can be removed completely. All sources of ignition will be prohibited near tanks as long as any fuel vapors are present. No work on fuel tanks will be started during electrical storms or when one is nearby, or when the wind conditions are such that fuel vapros might be carried into hazardous areas. Personnel will take special care not to carry matches, lighters, or other potential ignition sources into empty fuel tanks during cleaning or repair operations.

All personnel engaged in cleaning or inspecting bulk storage tanks will observe all existing safety measures pertaining to this hazardous operation. Any man entering an empty tank will wear supplied air respirator equipment containing a speaking diaphragm to provide effective communications between workers within and without the tank. The equipment will be used until all vapor producing sediment has been removed from the tank and the air is free of toxic materials. Care will be taken to keep protective equipment in good working order at all times. Workmen entering tanks will wear clean clothing from the skin out, covered by white coveralls. Suitable, first-quality protective gloves and boots will be worn. Work clothing which becomes soaked with sludge or fuel will be taken off immediately and the worker will quickly bathe and put on fresh clothing before returning to the job. At the end of the day, work clothes will be removed for laundering, and fresh clothes will be put on the next day. All persons engaged in interior tank operations will bathe at the end of each job and immediately after each day's owrk. Breathing apparatus, boots, gloves, and tools will be cleaned at the end of each day and after any job is completed.

Sludge which has been removed from a tank will be kept wet until it can be buried in a safe location.

Anytime a bulk storage tank must be entered for inspection, cleaning or repairs, the work will be approved by the major command having jurisdiction. The installation Liquid Fuel Facilities Engineer and the Industrial Hygiene Engineer, or their representatives, will supervise the operations, regardless of whether the work is being done by Air Force personnel or qualified contractors. All persons who enter tanks will be in good physical condition. Colds, fatigue, overheating or poor health will only add to the already present personnel hazards. No person with a punctured ear drum will be allowed to enter fuel tanks; the vapor-laden air may be drawn through the injury and into the body. As previously stated, all persons working inside fuel tanks will wear clean clothing of the proper type and specified protective equipment. Responsible personnel will be stationed outside the tank to keep a careful watch on those inside.

All tank cleaning operations will be conducted according to existing Air Force regulations and directives. Approved explosion-proof equipment will be used inside bulk fuel storage tanks.

Fuel oil leaks are detected by visually checking all valves, piping and auxiliary equipment.

SAFETY PROCEDURES. Static electricity is a constant source of danger, particularly when generated near fuels or flammable vapors. It has been responsible for starting many fires which have resulted in extensive property damage and personal injuries. Static electricity is created primarily by the contact and separation of two unlike substances or by almost any sort of motion of persons or material. High static electrical charges are created by persons walking, by moving rubber-tired vehicles, when liquid drops through space, and when petroleum products are pumped through lines and hoses. Although static charges are usually short-lived, they will often produce sufficient heat to ignite flammable gases, vapors, dust or other flash point materials, particularly during dry, cool weather.

While the generation of static electricity cannot be prevented, the sparking hazard can be effectively controlled by grounding, bonding or humidification. Grounding and bonding are particularly important in fueling operations, paint and dope shop work, aircraft and vehicle maintenance, ammunition handling, rocket and missile operations, compressed gas use, and in many other daily Air Force operations.

Static electricity is dangerous -- first, because it cannot be seen; and second, because its potential hazrds are not commonly known. When the dangers associated with static electricity are fully understood by supervisory and operating personnel, they will readily recognize the need for implementing immediate and effective control measures. Since static electridity is generated primarily by bringing together and separating two unlike substances, or by motion of almost any description, the use of effective grounding and bonding measures will greatly reduce the static electrical hazard.

A drop of liquid falling through space can build up charges of 10,000 volts in a split second under proper conditions; it begins to spark or arc at about 300 volts; staticcharges of ony 1500 volts will ignite gasoline fumes; a person walking across a dry area creates many times the voltage needed to create a spark to ignite gasoline.

Grounding. Grounding is probably the most practical way to control static charges which build up within an object will be carried off harmlessly, neutralizing the difference in electrical potential. Special grounding procedures, given in applicable Air Force directives, will be observed by operations personnel in all operations (figure 4-2). Grounding connections will be made to clean, unpainted surfaces.

Bonding. Effective bonding will eliminate the differential in electrical charge potentials which may exist or be generated between two objects. By connecting the two objects with a bonding wire attached to clean, unpainted surfaces, a static electrical discharge connot occur between these objects. Bonding is just as essential as grounding. and is invariably used together with static grounds. Although bonding will equalize the charge between two electrically connected objects, the objects themselves may still be highly charged. By connecting a ground wire to the bonded objects, this charge will be drained off without danger. Conductive greases and "V" belts on shaft pulleys are examples of effective bonding.

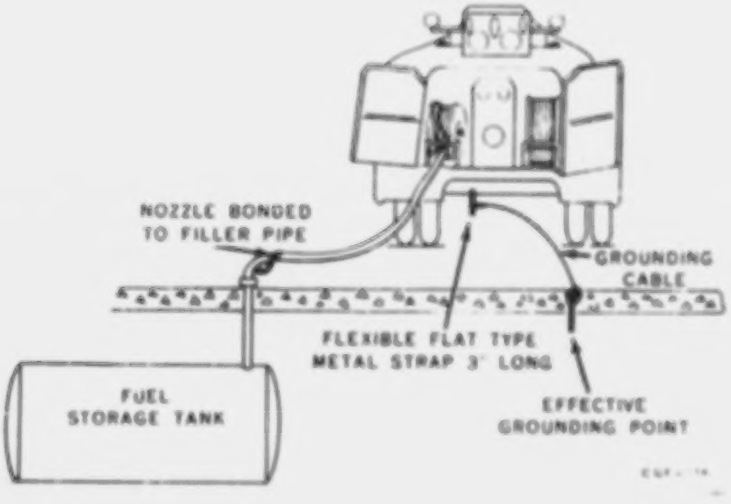

NOZZLE BONDED TO FILLER PIPE
GROUNDING CABLE
FLEXIBLE FLAT TYPE METAL STRAP 3' LONG
EFFECTIVE GROUNDING POINT
FUEL STORAGE TANK

Figure 4-2. Grounding and Bonding Systems
for Fueling a Storage Tank

FILLING TANK. When filling an oil storage tank be sure to follow the correct procedures. 1) Make sure that all storage tank vents are open. 2) Provide a grounding connection. 3) Open and fill line valve to tank. 4) Fill the tank to the desired level but not more than 95 percent of capacity. This is to allow for expansion of the oil. 5) Before and after receiving oil, record the tank level. 6) Close fill line. 7) Remove grounding connection.

TYPES OF FUEL OIL SUPPLY SYSTEMS. Oil is transferred from the storage tanks to the burners by either force pumps or gravity. Since it is not practical to maintain accurate regulation to compensate for varying loads, provision in some systems must be made to return unused oil back to the storage tank, or recirculating it through the supply system. The following paragraphs are devoted to a discussion of some of the most important fuel oil supply systems.

Single-Pipe, Gravity-Feed Oil Supply System. These are used in small space heater installations. An illustration of this type system is shown in figure 4-3. In this system, the oil storage tank is installed at a higher level than the burner. This allows the oil to flow to the burners by gravity. No provision is made for the return of unused oil to the storage tank since the oil flow is controlled by the amount that is used by the burner.

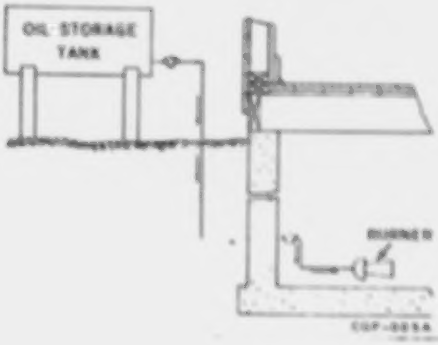


Figure 4-3. A Single-Pipe, Gravity-Feed Oil Supply System

Single-Pipe, Forced-Feed Oil Supply System. This system is usually used where it is impossible to use a one-pipe, gravity-feed system. In this type system, the storage tank is usually below the level of the burner as illustrated in figure 4-4. An oil pump, usually a positive displacement type, is installed in the system to force the fuel oil to the burner. This system recirculates the unused oil through the pump.

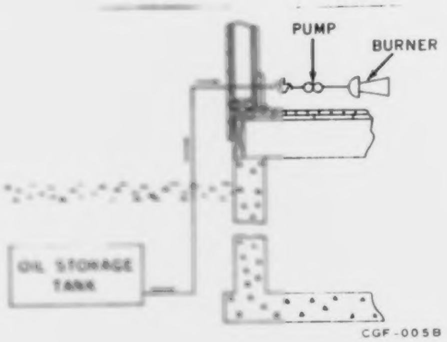

PUMP
BURNER
OIL STORAGE TANK
CGF-005B

Figure 4-4. A Single-Pipe, Forced-Feed Oil Supply System

Double-Pipe, Gravity-Feed, Forced-Return Oil Supply System. Fuel oil supply systems of this type are designed for larger installations than those mentioned previously. The fuel supply line in this system is esentially the same as a single-pipe gravity-feed system. The difference between the two systems lies in the methods of handling excess fuel oil. This is accomplished in this system by the addition of a fuel oil return line. Figure 4-5 shows a diagram of this system. Extreme care must be exercised when operating a system of this type, since failure of the return pump may cause the burner to flood and cause a pool of oil in the combustion chamber.

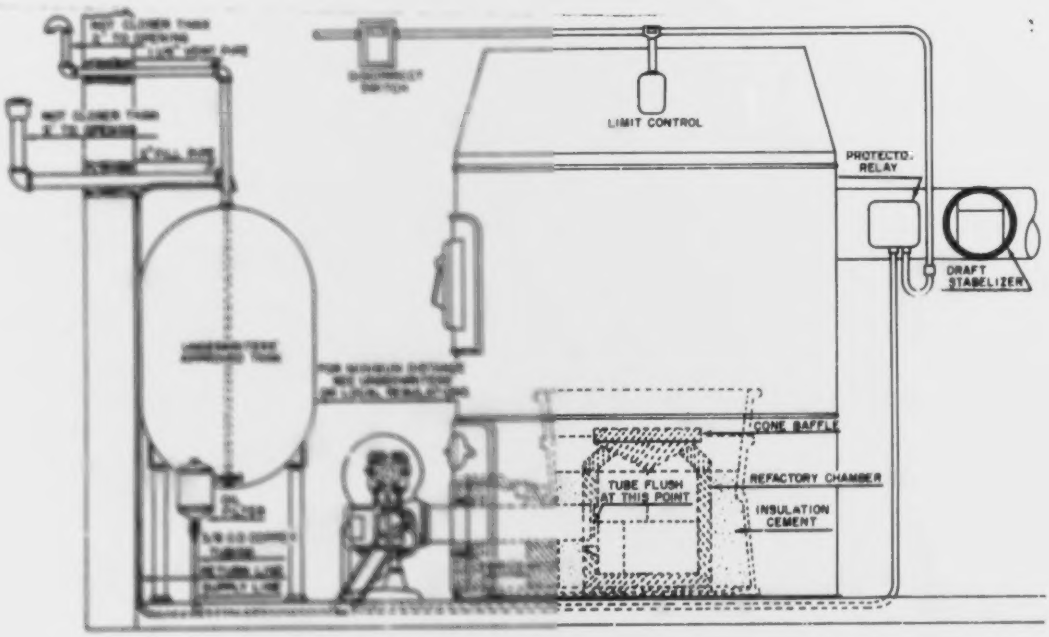

LIMIT CONTROL
PROTECTO. RELAY
DRAFT STABELIZER
CONE BAFFLE
REFACTORY CHAMBER
TUBE FLUSH AT THIS POINT
INSULATION CEMENT

Figure 4-5. A Double-Pipe Gravity-Feed Forced Return Oil Supply System

**Double-Pipe, Forced-Feed, Gravity Return Oil Supply System.** This type system is perhaps the most common found in central heating plants. A diagram of it is shown in figure 4-6. This system is similar to a two-pipe system. The fuel oil is forced to the burner by a pump, and the excess oil is returned to the storage tank by gravity.

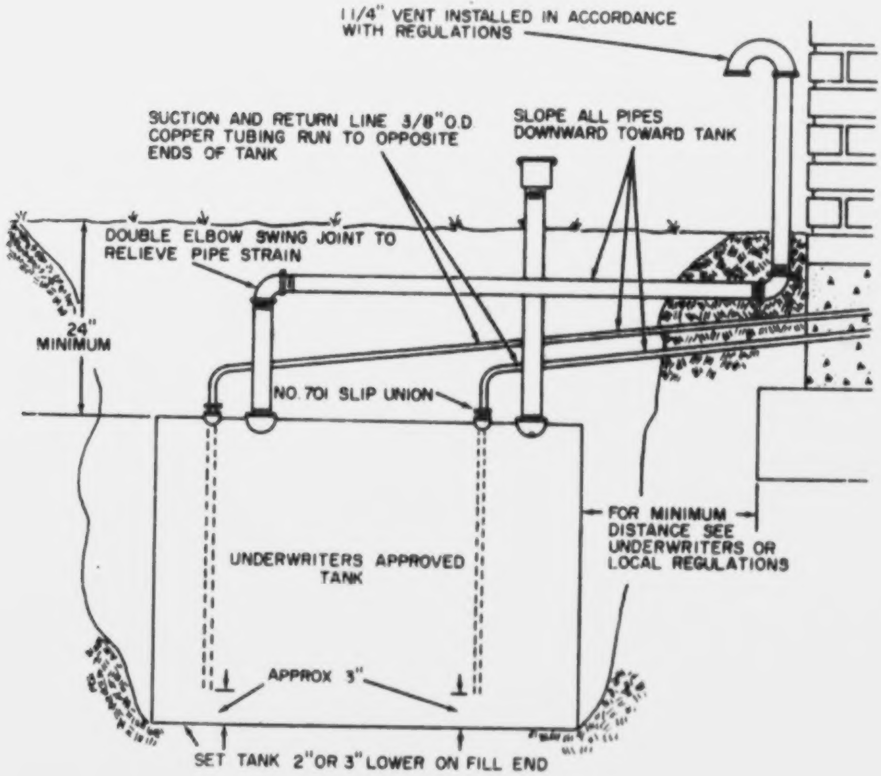

1 1/4" VENT INSTALLED IN ACCORDANCE WITH REGULATIONS
SUCTION AND RETURN LINE 3/8" O.D COPPER TUBING RUN TO OPPOSITE ENDS OF TANK
SLOPE ALL PIPES DOWNWARD TOWARD TANK
DOUBLE ELBOW SWING JOINT TO RELIEVE PIPE STRAIN
24" MINIMUM
NO. 701 SLIP UNION
FOR MINIMUM DISTANCE SEE UNDERWRITERS OR LOCAL REGULATIONS
UNDERWRITERS APPROVED TANK
APPROX 3"
SET TANK 2" OR 3" LOWER ON FILL END

Figure 4-6. A Double-Pipe Forced-Feed Gravity Return Oil Supply System

**INSPECTION AND MAINTENANCE OF FUEL OIL PIPING SYSTEMS.** Inspect oil piping systems at least daily. Look for any indication of leaks at all pipe joints such as elbows, tees unions, valves, etc. Any unusual conditions or evidence of abuse of the fuel oil supply system should be reported.

**MAINTENANCE OF OIL PIPING SYSTEM.** Make repairs or replacements as indicated by inspection. Replace gaskets and packing if necessary. Paint piping to protect against exterior corrosion and replace damaged insulation as required. Repair or replace damaged piping, tracers, hangers, supports, etc. Protect underground piping with suitable protective coatings and provide good groundwater drainage form the underground pipe area.

**VALVES.** Check condition and operation of valves. Manual valves are normally gate valves installed in the supply lines and check valves are installed in the return lines to prevent backflow due to gravity.

STRAINERS. Strainers are used in piping systems to remove foreign material from the fluid before it passes into equipment. Loose dirt, rust, scale or other foreign material can cause malfunctions and costly damage if they enter vital equipment. The strainer screen is usually made of thin-sheet bronze, monel, or stainless steel. In some strainer designs, the screen or basket is removed for cleaning; in others, the strainer has a valve to blow out foreign material. Always clean strainers when there is a pressure drop through them.

Figure 4-7 illustrates the kind of pipeline strainer normally used. A typical duplex fuel oil strainer is shown in figure 4-8.

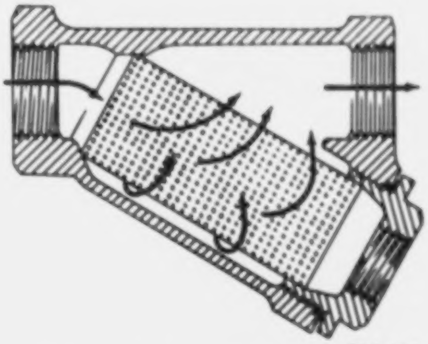


Figure 4-7. Pipeline Strainer

This unit has two strainers in one body. It is constructed in such a manner that the flow of fuel can be directed through either of the strainers by the use of the hand lever. In this way, one strainer can be cleaned while the other is in use.

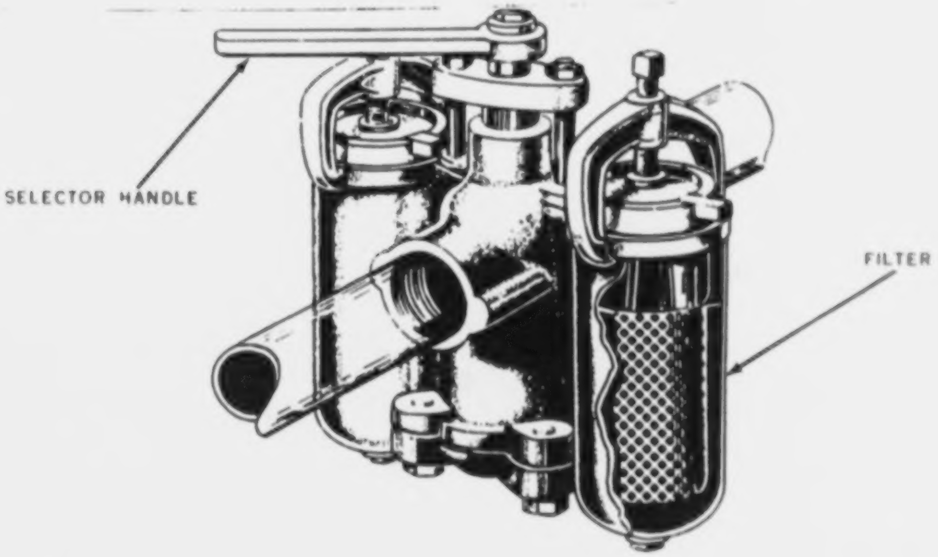


Figure 4-8. A Duplex Fuel Oil Strainer

PUMPS. The fuel pump used to pump fuel oil is a rotary positive displacement pump. They discharge a definite quantity of liquid for each revolution of the shaft. They use rotating cams, screws, lobes, sliding vanes or gears to impart pressure to the liquid. Two commonly used ones are the rotary screw and rotary gear.

ROTARY SCREW. A rotary screw pump is a positive displacement pump that will discharge a definite quantity of liquid for each revolution of the shaft. This is done by placing a set of screw type gears together. Figure 4-9. As the power rotor turns it causes the idler rotors to turn also, but in the opposite direction. By the screws meshing together a suction is created causing oil to enter the pump. The oil is then drawn between the screws and forced to the center of the pump where it is discharged.

Figure 4-9. Rotary Screw Pump

ROTARY GEAR. A rotary gear pump like the rotary screw is also a positive displacement pump. The moving parts consist of two gears which rotate in opposite directions with the teeth meshing. This creates a partial vacuum which causes the liquid to enter the pump. The liquid first fills the spaces between gear teeth as they separate on the suction side. Then, it is carried to the discharge opening in the pump. The discharge is even and without pulsations. Figure 4-10.

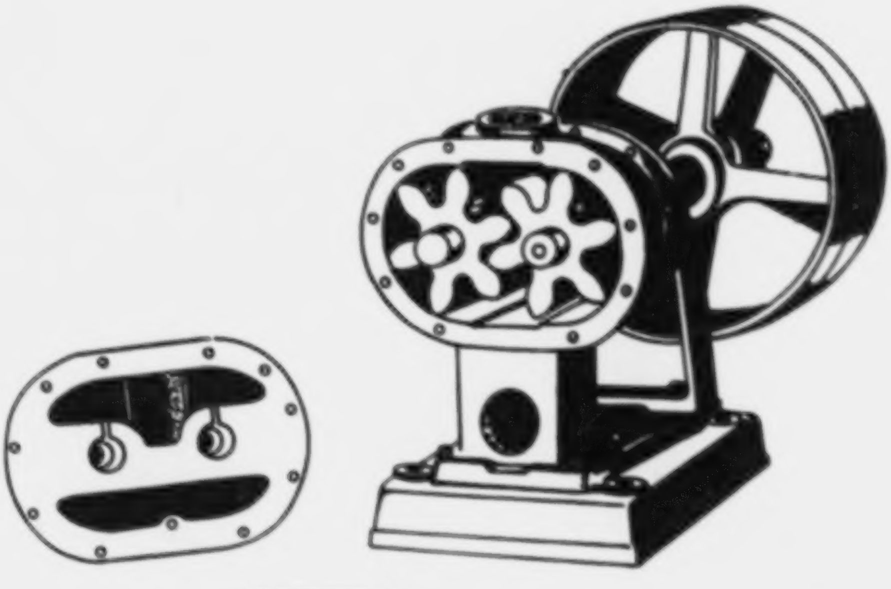


Figure 4-10. External Gear, Power Rotary Pump with Cover Removed

Rotary Pump Installation, Operation and Maintenance

INSTALLATION. In all installations, the pump, the driver and the controls must be readily accessible for regular maintenance and repairs. Pump suction and discharge piping connections are not necessarily of the same size as the system leading to or from the pump. Changes in the system to fit the pump connections should be as close to the pump as possible. If a reducer is used in the section piping, it should be tapered with the top flat to avoid a air pocket. Suction and discharge piping must be supported so that no strain is transmitted to the pump. Normally, the pumps are assembled at the factory and they come properly aligned. However, all base plates are flexible to some degree, and each pump, regardless of type, must be realigned after installation in accordance with the manufacturer's specifications. Alignment can be maintained when the base plate has been properly bolted to it. It is common practice for the manufacturers to include a pumping system trouble analysis guide for you to follow in installing and operting the various types of pumps.

OPERATION. Before operating a rotary pump insure the following.

(1) Rotary pumps depend upon clearances for efficiency. Keep grit or other abrasive material out of the liquid being pumped to prevent excessive wear and rapid loss of efficiency.

(2) Always start the pump with both suction and discharge valves open to prevent overload of motor and damage to the pump.

(3) A pressure relief valve which discharges back to the suction side of the pump is usually provided on the outlet piping. Adjust this valve for a relief pressure which will not overload the motor. Make sure the valve seats properly, otherwise loss of efficiency results.

MAINTENANCE

DAILY. The daily inspection and maintenance requirements for a rotary pump include checking for abnormal vibration and noise, abnormal pressure and flow conditions, excessive or inadequate packing leakage (water-cooled bearing), hot bearings and hot stuffing box. Discrepancies found during this daily inspection will dictate the maintenance requirements.

MONTHLY. A monthly inspection would include a repeat of the daily inspection. In addition, examine the external gear and bearing housings for correct lubricant level and condition.

ANNUALLY. At least once a year dismantle the pump and inspect for excessive clearances, improper timing gear setting, corrosion, erosion, wear or other defects of parts, incorrect alignment (hot and cold), transmission of strains from piping to pump, defective gear teeth, improper operation and setting of relief valve valve (if equipped), defective suction and discharge valves, improper calibration of pressure gauges, thermometers and flow meters, and defective strainers.

Maintenance Requirements. Repair or replace all defective parts found during the yearly inspection. When installing new timing gears, be sure to follow the manufacturer's instructions for installation, adjustment, and key slotting. When internal clearances increase above the permissible limits, the capability and efficiency of the pump decreases. Replace work shaft sleeves or have them rebuilt by metalizing.

## SAFETY PROCEDURES WHEN OPERATING MECHANICAL EQUIPMENT

Although accidents due to unguarded machinery occur less frequently than those with moving machine parts, they are generally severe and often result in permanent disability of the operator. Improved machine design, or the installation of mechanical safeguards, removes from the operator much of the dependence for safety. Two principles of machine guarding, which includes all equipment from the prime movr to but excluding the point of operation; and point-of-operation guarding, the area where the actual work of the machine takes place. Applicable standards prescribed herein or as outlined by industrial practices will be consulted for detailed information on the use of machine guards.

When machinery and powered transmission equipment are not guarded as part of their design, suitable mechanical guards such as enclosures or barricades will be temporarily or permanently installed to eliminate the possibility of injury resulting from contact with moving parts or hazardous substances.

Machine controls will be conveniently located for the operator. In the use of all conveyor systems, stop switches will be installed at intervals not exceeding 100 feet and at lesser intervals where obstructions are located in the path of travel--that is, stop switches will be so located that they may be reached without changing elevation of travel, to allow immediate shutdown in an emergency. Stop switches will never be made inaccessible by covering or blocking off. Power controls will be of a type that can be locked in the "OFF" position when repairs are necessary. Suitable identification signs will be posted at control switches. Machine operators will not leave machinery running unattended. For maximum safety, exposed shafting less than eight feet above the floor will be completely enclosed in a stationary metal guard. All pulleys, belts, ropes, chain drives, gears, sprockets, chains, couplings and clutches that are located less than eight feet above the floor or work area will be properly guarded.

Proper clothing, such as explained on day-one, unit-one, will be worn and be in suitable serviceable condition when personnel are working around any type of mechanical equipment.

## SUMMARY

Crude oil that comes out of the ground is broken down to different types of fuels. The oil that we use is classified as either distillates or residuals. Distillates are the lighter oil and generally do not need to be heated to be burned. The oil that falls into this category are Grades 1 and 2.

The remaining oil left over after the distillation process are called residuals. Because they are the "bottom" oils they are much heavier than the lighter or distillate oils. Since they are heavier they generally must be heated so that they can be transported and burned. The oils that fall into this category are Grades 4, 5, and 6.

Since large amounts of oil are necessary, storage tanks must be available to hold this oil. These tanks can be either aboveground or belowground. Each of these tanks must have a fill pipe and a vent pipe to allow the tank to be filled.

On rare occasions personnel may have to enter a storage tank for cleaning or for maintenance. Whenever entering a tank be sure to follow the necessary safety precautions to eliminate the possibility of an explosion.

In order to transfer the oil from the storage tank to the burner different types of piping systems have bee designed. Depending on the location of the storage tank and the type of system, oil can be transferred to the burner by gravity or by pump.

Oil piping systems consist of many components such as valves, strainers, pumps and, of course, the pipe itself. Because of the many components on a piping system care must be taken to assure that each component works as it is suppose to. This can be done by inspecting these components periodically. If any problem is found, arrangements should be made for repair or replacement of the defective part.

## QUESTIONS

1. What are the two major classifications of fuel oils?

2. What does the term "viscosity" mean?

3. What are the components of fuel oil storage tanks and what is the purpose of each?

4. What is the maximum amount that a fuel oil tank should be filled?

5. What type of oil piping system will flood the combustion chamber if the return pump fails?

6. What type of pumps are used to pump fuel oil?

REFERENCE

AFM 85-12, Volume 1, Operation and Maintenance of Central Heating Plants and Distribution Systems

## SECTION II

## DOMESTIC AND INDUSTRIAL OIL BURNERS

### OBJECTIVE

The objective of this study guide is to identify the procedures for maintaining an oil burner.

### INTRODUCTION

Although fuel oil is a mixture of hydrocarbons in a liquid state, it will not burn until the burner has prepared it for combustion. In addition to correctly proportioning and mixing the fuel and air, the burner must vaporize or gasify the fuel oil.

With the light fuel oils, vaporization can be accomplished by direct application of heat. The heavier and less volatile oils, however, must be atomozed before they can be vaporized. Since the lighter fuels are not widely used in central heating plants, we will discuss only burners that utilize the automization process in fuel preparation.

Oil burners may be classified according to the type of fuel oil each burner consumes as well as the type of heating system it serves. According to this classification, oil burners may be divided into the two groups, those used in conjunction with domestic heating systems and those used in industrial heating systems.

### INFORMATION

### THEORY OF CONSTRUCTION

Oil burners and equipment for industrial use are usually designed to burn lower-cost, heavy fuel oils such as Grade Nos. 4, 5 and 6. The viscosity of these oils is much greater than that of the lighter domestic grades. For this reason, the equipment required for satisfactory storage, pumping and combustion differs considerably from that used in domestic oil-burning systems.

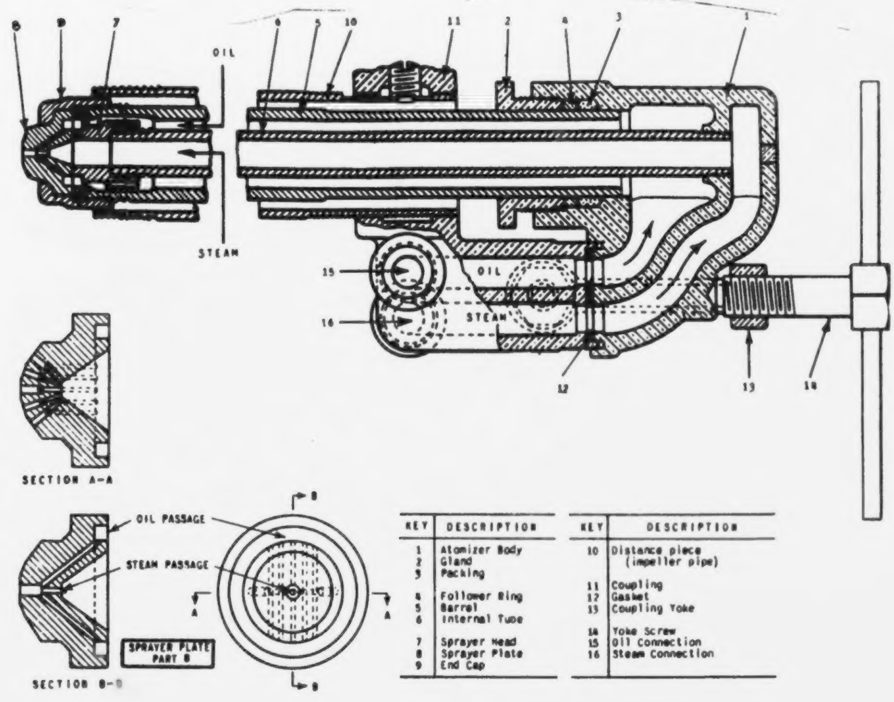
Oil burners for industrial use are usually classified according to the method used for atomizing the oil. There are three types of industrial oil burners used by the Air Force. These are: atomizing oil burners, mechanical oil burners and horizontal rotary burners.

### PRINCIPLES OF OPERATION

ATOMIZING OIL BURNERS. Atomizing oil burners use either steam or air as the operating medium. Steam is the most common of any of the nonmechanical types of oil burners, and require only a minimum amount of equipment. They handle commercial oil Grade numbers 4, 5, and 6, and require a steam pressure varying from 50 to 125 psig. When the burner is operating, it maintains a pressure differential between the steam and oil pressure of about 20 to 25 psig.

They consist of a properly formed jet-mixing nozzle to which oil and steam or air are piped. The atomizing medium mixes with fine particles of fuel passing through the nozzle, and the mixture is projected into the furnace. Nozzles may be of the internal (inside) mixing type or the external (outside) mixing type. In the first type, the oil and steam or air are mixed inside the burner; in the second type, they are mixed at the burner orifice exit.

The heat output of the burner for a given burner tip (sprayer plate) is changed by varying the oil pressure up to the maximum allowed. Higher capacities can be obrained by changing the burner tips. Combustion air enters through a register where adjustable vanes help control the shape of the flame. An impeller plate attached to the furnace end of the burner imparts a swirling motion to the air to promote combustion and mixing. Figure 4-11 illustrates a fuel oil, steam atomizing burner. The figure shows a longitudinal section of the burner and detailed sections of the burner tip (sprayer plate).


8
9
7
OIL
6
5
10
11
2
4
3
1
STEAM
15
OIL
16
STEAM
12
13
14
SECTION A-A
OIL PASSAGE
STEAM PASSAGE
SPRAYER PLATE PART 8
SECTION B-B
B
A
A
B

| KEY | DESCRIPTION |
|---|---|
| 1 | Atomizer Body |
| 2 | Gland |
| 3 | Packing |
| 4 | Follower Ring |
| 5 | Barrel |
| 6 | Internal Tube |
| 7 | Sprayer Head |
| 8 | Sprayer Plate |
| 9 | End Cap |
| 10 | Distance piece (impeller pipe) |
| 11 | Coupling |
| 12 | Gasket |
| 13 | Coupling Yoke |
| 14 | Yoke Screw |
| 15 | Oil Connection |
| 16 | Steam Connection |

Figure 4-11. Fuel Oil Steam Atomizing Burner

## Mechanical Oil Burners

Mechanical burners use oil pressure and especially designed nozzles to atomize the fuel. Atomization results when oil under high pressure (100-225 psig) passes through a small orifice and emerges as a conical mist. The orifice that atomizes the fuel is often aided by a slotted disk that whirls the oil before it enters the nozzle. Air for combustion is supplied in a manner similar to that used for steam atomizing oil burners. Heat output is also varied as in steam atomizers. Figure 4-12 illustrates a longitudinal section of a mechanical atomizing burner and detailed sections of the nozzle body and sprayer plate.

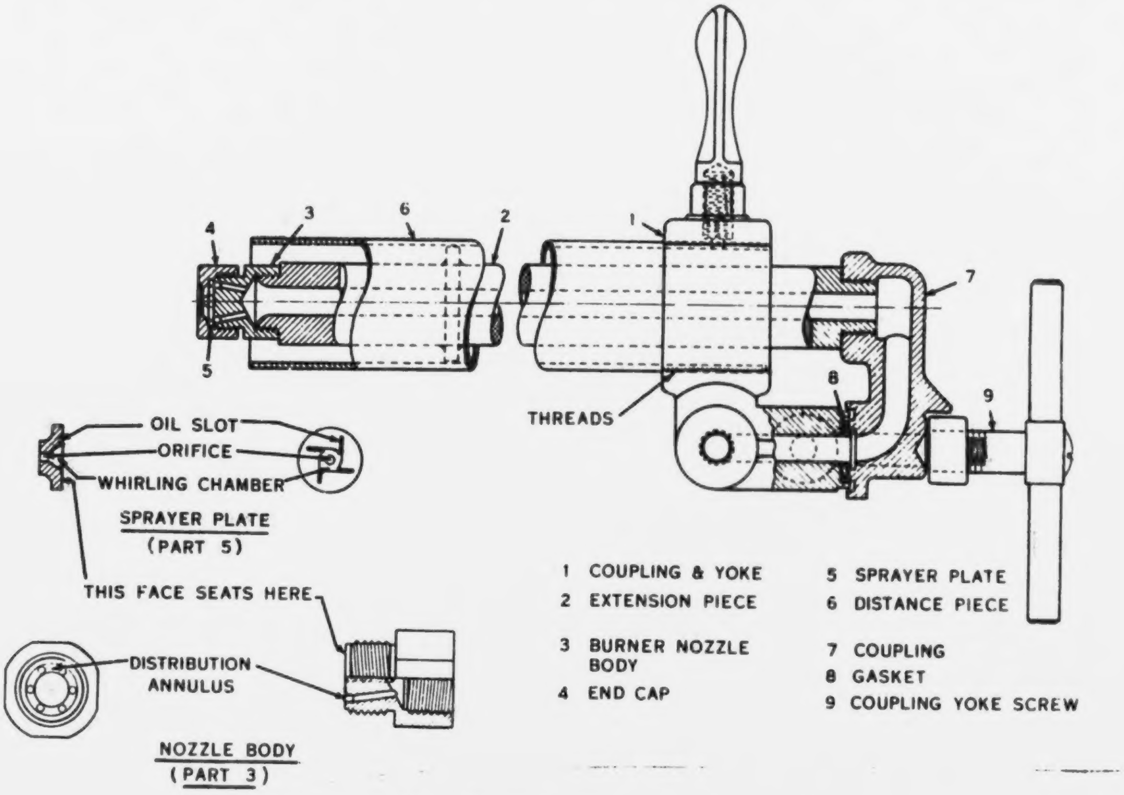

4
3
6
2
1
7
5
8
9
THREADS
OIL SLOT
ORIFICE
WHIRLING CHAMBER
SPRAYER PLATE
(PART 5)
THIS FACE SEATS HERE
DISTRIBUTION ANNULUS
NOZZLE BODY
(PART 3)
1 COUPLING & YOKE
2 EXTENSION PIECE
3 BURNER NOZZLE BODY
4 END CAP
5 SPRAYER PLATE
6 DISTANCE PIECE
7 COUPLING
8 GASKET
9 COUPLING YOKE SCREW

Figure 4-12. Fuel Oil Mechanical Burner

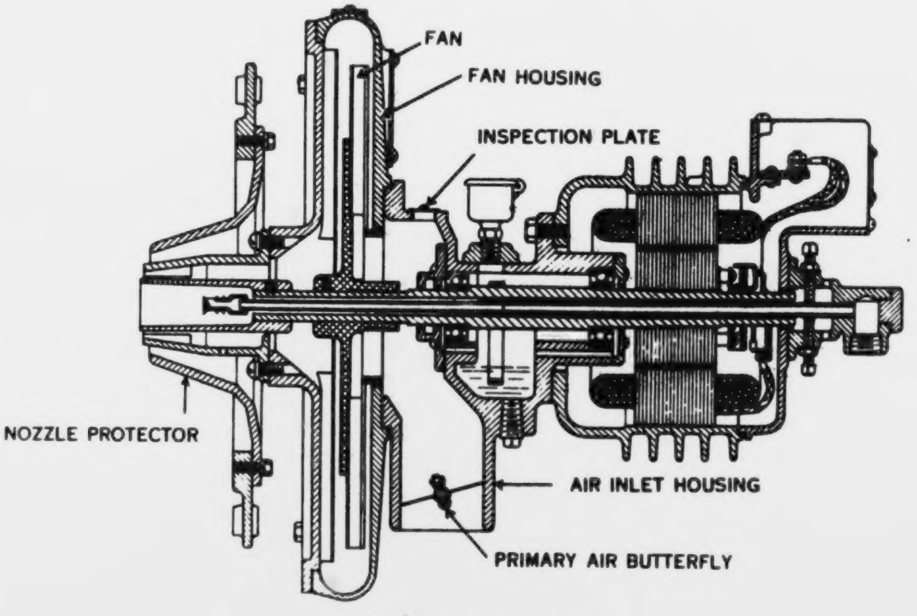

FAN
FAN HOUSING
INSPECTION PLATE
NOZZLE PROTECTOR
AIR INLET HOUSING
PRIMARY AIR BUTTERFLY

Figure 4-13 Horizontal rotary oil burner.

Figure 4-13. Horizontal Rotary Oil Burner

## Horizontal Rotary Burner

The rotary burner (figure 4-13) compares favorably with the pressure-atomizing burner in the following respects. There are no small orifices to plug up, oil can be used at a lower temperature, and any of the rotary burners have wider ranges of fuel burning capacity than high-pressure gun-type burners.

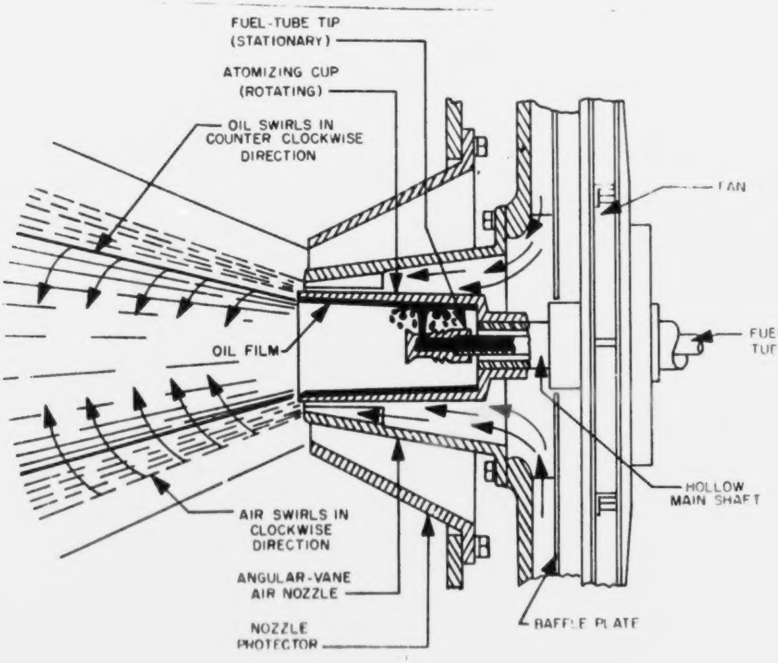


Figure 4-14. Horizontal Rotary Burner

OPERATION. The rotary-type burner has three main parts: rotating atomizing cup, stationary fuel tube and fan. Illustrated in figure 4-14 are these and other parts of the horizontal rotary burner. The atomizing cup and fan are driven at the same speed by a director. Oil is fed through the stationary tube to the inner surface of the atomizing cup. It spreads over the surface of the cup, which is turning at a speed of 3450 or 4000 RPM (depending on whether it is motor- or turbine-driven), flows to the edge of the cup, and is then thrown off. The rotating cup imparts a whirling motion to the oil as it travels to the edge, and the resulting centrifugal force separates the oil into fine particles as it leaves the cup. Primary air supplied by the fan is introduced around the outer edge of the rotating cup and give a whirling motion in the direction opposite to that of the oil. The streams of air and oil collide and are thoroughly mixed. The primary air which the fan supplies is only part of the air required for combustion in a burner operating at full capacity. The air supplied by the fan can be regulated by a damper located on the suction side. The damper is usually controlled along with the oil supply by automatic or manual controls. The shape of the flame is determined by the nozzle through which the air is discharged. The remaining or secondary air required to complete combustion is supplied through openings in the floor directly below the burner, or through passages in the wall around the burner.

Most rotary burners are manufactured differently, so the parts of one manufacturer's burner cannot be interchanged with another. Therefore, the manufacturer's instructions for operating and maintenance must be studied carefully before an operator attempts to operate a rotary burner.

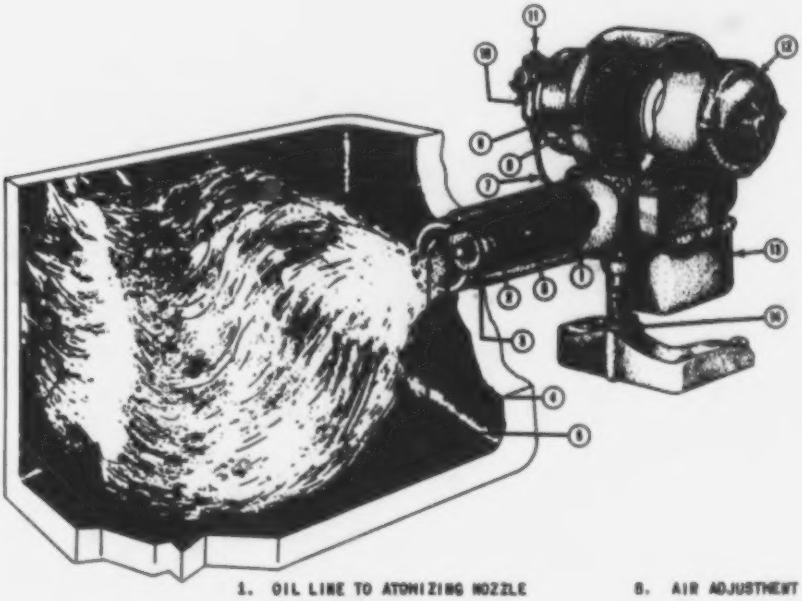
Complete installation, operation, troubleshooting and preventive maintenance procedures for industrial oil burners should be procured from the manufacturer of the oil burner.

### Type of Domestic Burner and Components

As was stated previously, oil burners are classified according to the type of fuel burned. The domestic oil burners burn fuel oil grade numbers 1 and 2. These are your distillate type fuel oils. The oil burer in most oil-fired domestic-heating units is the gun-type burner.

### Uses of the Gun-Type Oil Burner

High-pressure atomizing burners vaporize, atomize, and deliver a predetermined quantity of oil and air to the combustion chamber where the mixture is burned. These oil burners operate automatically and maintain a desired temperature. The oil system of a pressure atomizing burner consists of a gear pump, a pressure-regulating valve, a shutoff valve, and an atomizing nozzle. The air system consists of a power-driven fan, a device to throttle the air inlet, an air tube which surrounds the nozzle and electrode assembly, and vanes to mix the air and oil properly. Both the fan and oil pump are normally connected directly to the motor. Electric ignition is almost universally used. The electrodes are located near the nozzle. (See figure 4-15)



1. OIL LINE TO ATOMIZING NOZZLE
2. ELECTRODE
3. DEFLECTOR CONE
4. ATOMIZING NOZZLE
5. DEFLECTOR BLADES
6. BLAST TUBE ASSEMBLY
7. OIL LINE FROM PUMP TO FUEL TUBE
8. AIR ADJUSTMENT
9. FAN
10. PUMP
11. PRESSURE REGULATOR VALVE
12. MOTOR
13. IGNITION TRANSFORMER
14. ADJUSTABLE LEG

Figure 4-15. Typical High-Pressure Gun-Type Burner

The gun-type burner is used primarily in hot water heaters, warm air furnaces, small hot water boilers, low pressure steam boilers and somtimes as ignition for horizontal rotary burners.

Components of the Gun-Type Oil Burner

**BURNER MOTOR.** The electric motor drives the fan and fuel pump. Usually it is a specially designed split-phase type that is an integral part of the burner. These motors need very little maintenance, since they only require oiling about twice per year. About 5 to 6 drops are sufficient. Some important factors to remember when replacing the motor is that the revolutions per minute, rotation and mounting must be the same as for the motor being replaced. (See figure 4-16)

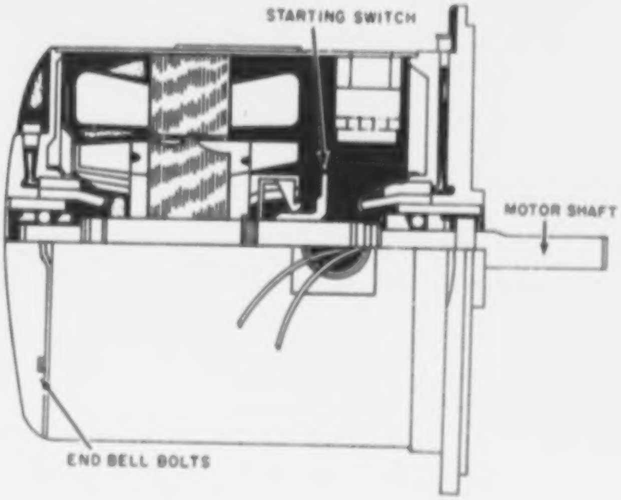


Figure 4-16. Cutaway View of an Electric Motor

**FAN.** The fan wheel (figure 4-17 within the burner fan housing is driven directly from the motor shaft, and it provides the necessary air to support combustion. This fan wheel is of multi-blade design and is capable of furnishing an adequate air supply to the blast tube. The volume of air handled by the fan is readily controlled by an adjustable air shutter located on the housing which controls the air intake to the burner.

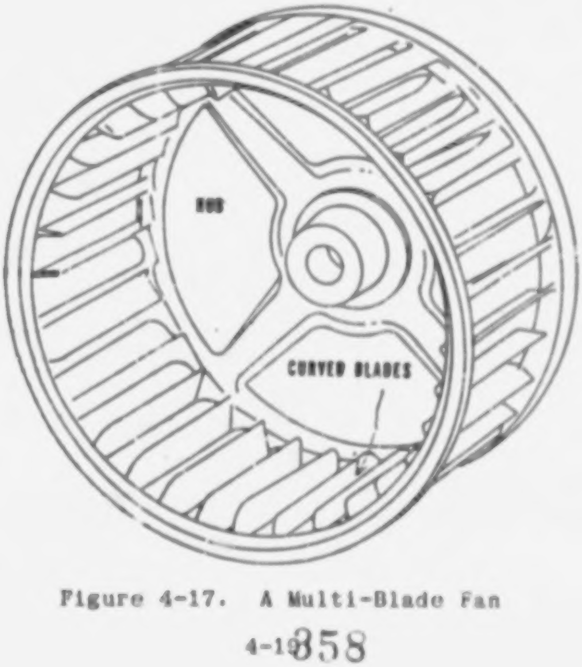


Figure 4-17. A Multi-Blade Fan

**FUEL PUMP.** The fuel pump for the gun-type burner is a rotary positive displacement gear pump. The pump shaft is connected to the burner motor, which drives the pump, by a flexible coupling. The flexible coupling is used to absorb the shock when the burner motor starts up.

**Single-State Fuel Units.** The single-stage fuel unit (figure 4-18) has one pumping unit which takes oil fed by gravity into the unit and applies pressure to force fuel through the nozzle. This single-stage unit is, therefore, best adapted where an elevated tank is used, so that oil is fed by gravity to the burner. Although the single-stage pump can be used for overhead piping installations, if necessary, there is some danger of pump noise. The two-stage pump is, therefore, recommended for such an installation.

**Two-Stage Fuel Units.** The two-stage fuel unit (figure 4-19) usually looks exactly like the single-phase unit, but it contains two complete pumping units. One pump sucks oil from the tank to the unit and then delivers the oil to the second pump, which applies the pressure required at the nozzle. This two-stage unit is recommended for use with all outside underground tank installations and for inside tanks connected to the burner through overhead piping. Normally, you use a two-pipe system with a two-stage fuel unit. An adjusting screw on the pressure-regulating valve enables the operator to vary the pressure from 80 to 140 psi.

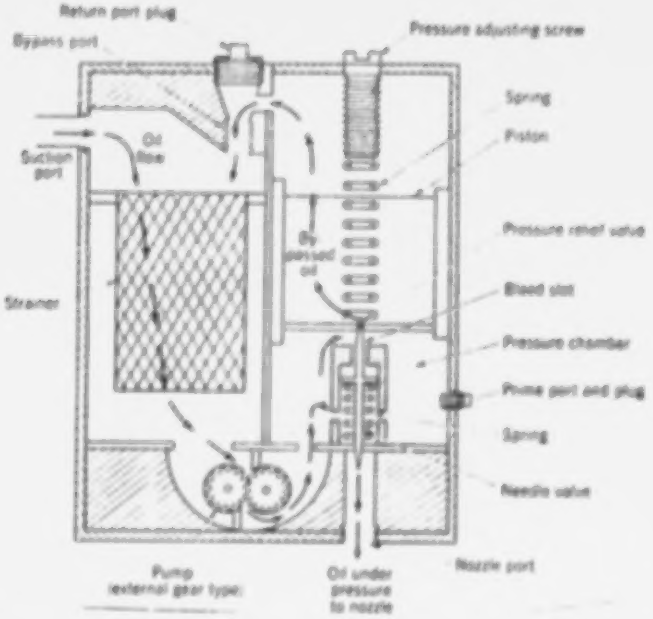

Return port plug
Bypass port
Pressure adjusting screw
Spring
Piston
Oil flow
Suction port
By passed oil
Pressure relief valve
Bleed slot
Strainer
Pressure chamber
Prime port and plug
Spring
Needle valve
Pump (external gear type)
Oil under pressure to nozzle
Nozzle port

Figure 4-18. A Single-Stage Fuel Unit

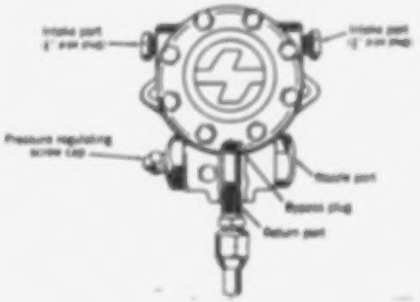

Intake port
Intake port
Pressure regulating screw cap
Nozzle port
Bypass plug
Return port

Figure 4-19. A Two-Stage Fuel Unit

NOTE: Changing the pump pressure will effect the gallons per hour (GPH) of the nozzle. Example: More pressure, more oil; less pressure, less oil.

In the case of a hum in the fuel tank, check the fuel pump for the anti-hum diaphragm. If it is broken or missing, replace it.

BLAST TUBE. The blast tube directs the air from the fan to the deflector vanes. The deflector vanes, in turn, swirl the air to help promote combustion. The blast tube also houses the fuel tube, electrode assembly, and nozzle assembly. Inside the blast tube, there is a status disk or stabilizer, which holds the fuel tube and electrode assembly in place.

NOZZLE ASSEMBLY. The nozzle assembly includes a nozzle adapter which is screwed onto the fuel tube and a nozzle which is screwed into the nozzle adapter. There is also a small strainer that is screwed onto the nozzle. This strainer catches any small impurities before they reach the nozzle orifice.

The nozzle on a gun-type oil burner is rated in gallons per hour (GPH). It has four separate functions:

--Governs the amount of fuel burned--this will depend on the size of the furnace or boiler. (Rated at 100 psig from pump.)

--Governs the angle of spray--this depends on the size of the combustion chamber or firebox.

NOTE: The angle of spray and gallons per hour or capacity of the nozzle will always be stamped on the outside of the nozzle.

--Detects the flow of the oil into a swirling motion, which, in turn, atomizes it.

--Determines the type of spray--this means the spray pattern and also the density of the spray pattern. The type of spray could be extra solid, semisolid, hollow and extra hollow.

ELECTRODE ASSEMBLY. The electrode assembly (figure 4-20) includes two separate electrodes which are partially covered by glazed porcelain insulators. A supporting clamp, which may be called a static disk or stabilizer, holds the electrodes firmly together along with the fuel tube inside the blast tube. The electrodes are used as igniters to light the fuel-oil from the burner.

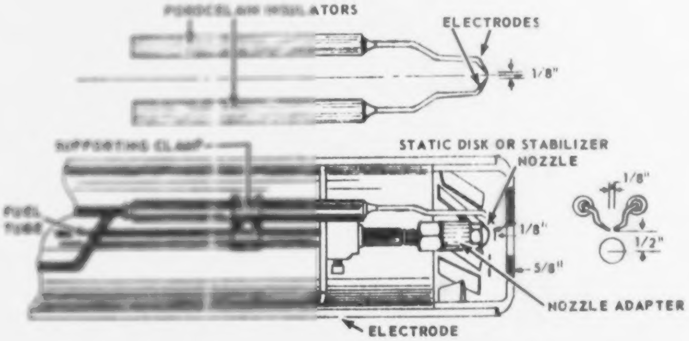


Figure 4-20. Details of Electrode Assembly

The electrodes must be adjusted properly in order to work. They must be 1/8" to 3/16" apart; 1/8" ahead of the nozzle; 1/2" above the center of the nozzle; and there should be a distance of 5/8" from the nozzle to the end of the blast tube.

The electrode ignition system may be either an intermittent or constant ignition. Intermittent would be when the electrodes arc and ignite the fuel-oil and then go out. A constant ignition would arc as long as the burner motor is operating. The type of ignition system will be determined by the type of primary control.

IGNITION TRANSFORMER. The ignition transformer (figure 4-21) is located on the burner housing. It is placed in different locations on different types of oil burners. The purpose of the ignition transformer is to provide the necessary voltage needed to jump the gap between the electrodes (10,000 volts). This creates a spark which ignites the oil spray coming out the nozzle. In case of failure, other than broken leads, the transformer must be replaced iwth a new or rebuilt unit having identical mounting holes.

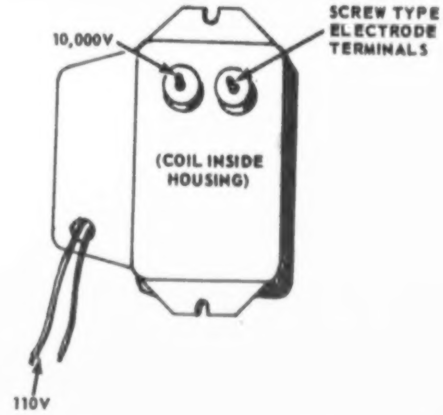


Figure 4-21. An Ignition Transformer

### Removing, Disassembling and Installing

Complete removal, disassembling and installation procedures for the gun-type oil burner should be procured from the manufacturer of the oil burner.

### Inspecting, Cleaning, Adjusting and Operating the Gun-Type Oil Burner

#### Starting the Burner

All of the wiring is properly checked, and the fuel system is connected after the installation of an oil burner and its operating controls. Then, it is the responsibility of the heating specialist to accomplish the operational functions established for the burner. The following job plan should be followed when you are starting the burner:

--Partially close the air shutter.

--Install the pressure gauge and petcock in the vent outlet.

--Make sure that the primary control has been reset.

--Set the thermostat above room temperature, check the limit switch and close the burner switch.

--Open the petcock to purge air from the system. Close it when clear oil flows from it. Set the oil pump pressure regulator to maintain 100 psig.

- If the burner stops before oil reaches the nozzle, allow the safety element in stack control to cool before pushing the reset button to restart it. Do not hold the relay in, because the safety element will overheat.

- Open the air adjustment slowly until the fire is perfectly clean.

- Set the draft for 0.02- to 0.04-inch water gauge over fire. This usually provides 0.04 to 0.06 inch at the flue.

- Make the final air adjustment after the burner has been operating long enough to warm the combustion chamber. Look through the balanced smoke pipe damper, using a drop light. Turn down the air supply to the burner until smoke is seen passing through the light beam in the smoke pipe. Then, open the air adjustment until the smoke disappears. Check this approximate setting with an Orsat adjusted to 10 percent $CO_2$. After two or three weeks of operation, recheck the adjustment to see that the draft and percent $CO_2$ are satisfactory.

- If oil shoots into the firebox at first without igniting, because of ignition difficulty or other cause, the oil will soak into the soft brick. Be sure that the relief door is open. The combustion chamber must be properly ventilated upon any misfire. Shut off the burner after a misfire when the burner is placed in operation and is igniting the oil that is in the combustion chamber. The oil-soaked brick will make the burner rumble and puff for a few minutes, until the oil has burned out. Never refire a burner when the combustion chamber is flooded; the excess oil must be removed before firing again. Always guard against a backfire; stand to one side of the relief or firing door when you are starting a burner.

Troubleshooting

The following information has been prepared to help the heating specialist locate and correct troubles which occur in oil burners. Common troubles and the checks which are made to correct them are listed as follows:

| TROUBLE | CAUSE | REMEDY |
|---|---|---|
| Oil Failure | Oil storage tank empty. | Refill. |
| | Nozzle clogged. | Remove the burner assembly. Clean or replace the nozzle. |
| | Strainer clogged. | Clean the line strainer, the fuel unit strainer, and/or the nozzle strainer. |
| | Internal bypass plug may not be in place when installing the burner with a return line. | Install the bypass plug. |
| | Restriction in suction line, other than clogged strainers. | Use a vacuum gauge to check the the line back to the tank. Use a bicycle pump, attached to the burner end of the line, to blow back any obstructions in the line. |
| | Vacuum leak in the suction line. | Locate and repair the leak. In extreme cases (restriction or vacuum leak in the suction line) it may be necessary to run a new suction line. |
| | Leaky pump shaft seal. | Replace the seal. |

| TROUBLE | CAUSE | REMEDY |
|---|---|---|
| Motor Failure | Bypass plug installed in fuel unit when used with single-pipe system, thereby building up excessive pressure and stalling the motor. May blow the fuses. | Remove the bypass plug. Check the fuel unit and the motor for possible damage. |
| | Motor starting switch dirty or sticking. | Remove the motor end bell and examine the switch assembly. If the remedy is not obvious, replace the switch assembly or change the motor. |
| | Motor condenser is burned out. | Short out the condenser. If the motor runs, replace the condenser. |
| | Motor is shorted or burned out. | Replace the motor with one of same rotation. |
| Ignition Failure | Transformer terminals are not connected. | Connect and properly tighten the terminals. |
| | Electrodes are not set properly. | Adjust the setting. |
| | Carbon on the electrodes. | Clean and check the setting. |
| | Weak transformer. | Replace transformer. |
| | Electrodes are cracked or grounded. | Replace the electrodes and adjust the setting. |
| Faulty Control Operation | Stack control helix is badly sooted. | Remove the control and clean the helix with a small brush. |
| | Stack temperature is too low because the fire is too small for the heating load. | Increase the GPH and adjust the fire for boiler size. |
| | Too frequent cycling of the thermostat. | Adjust thermostat for longer running cycles. Check wiring to thermostat heat anticipator. |
| Irregular Stack Temperature | Change in draft. | Install the draft regulator. |
| | Downdraft caused by obstruction such as trees or insufficient chimney height. | Remove the obstruction. Increase the chimney height or install an H-hood. |
| | Bad draft due to leaks in the chimney. | Other openings should be closed. |
| | Fluctuating flame. | Check burner operation. Nozzle may be partially clogged or there may be water in the oil. Fuel unit pressure may be set too low so that the oil delivery is not uniform. |

| TROUBLE | CAUSE | REMEDY |
|---|---|---|
| No Electric Current to Burner Circuit | Fuse Blown. | Replace the fuse, and determine what caused it to blow. |
| | Difficulty with the power source. | Notify the electrician. |
| | Break in the wiring or bad connection. | Check it with test equipment and repair it. |
| | Defective controls. | Repair or replace. |
| Burner Fails to Shut Off | Controls improperly wired. | Rewire the controls. |
| | Thermostat out of calibration. | Calibrate the thermostat. |
| | Wires shorted out. | Check with the test equipment and repair. |
| Smoke, Odor, Fumes | Improper burner adjustment. | Check the air and oil adjustments. |
| | Bad draft creating pressure in the chamber. | Check the overfire draft with the gauge and correct. |
| | Air cone burned away or fallen out. | Check the air cone on the end of the blast tube. Correct or replace it. |
| Burner Puffs When Starting. | Electrode is not properly set. | Reset the electrodes. |
| | Weak spark due to a ground in the burner assembly. | Check and correct. |
| | Weak spark, or no spark at all. | Check out the transformer and replace it if necessary. |
| Burner Short Cycling | Limit control is cuting off and on. | Check the wiring and location of the limit control; also check the thermostat. |
| | Thermostat differential is set too close. | Adjust for wider differential |
| Improper Flames | Oil pressure too high or too low. | Adjust the fuel pump for 100 pounds of pressure. Set the air shutter for the proper smoke reading. |
| | Poor draft. | Check the chimney and smoke pipe. |
| | Improper adjustment of the burner air shutter. | Adjust to produce an orange flame with no chimney smoke and no more excess air than necessary. |

| TROUBLE | CAUSE | REMEDY |
|---|---|---|
| Burner Noisy | Motor drive coupling is loose or worn. | Replace the worn parts. Check the alignment. |
| | Rigid electric or oil pipe connections at the burner. | Relieve the strain by installing flexible sections at the burner. |
| | Fuel unit is not reassembled properly. | Reassemble the fuel pump. |
| | Tank hum. | Install an anti-hum diaphragm. |
| Excess Fuel Consumption | Poor atomization. | Adjust to the proper flame. |
| | Excessive draft. | Readjust for a -0.02 inch overfire draft. |
| | Low $CO_2$ (high excess air). | Eliminate the air leaks in the furnace or boiler. Adjust the draft and improve the flame. |
| | Fire is too small for the boiler or furnace. | Increase to the proper GPH. |
| | Fire too large for boiler or furnace. | Decrease fire to proper GPH. |
| | Improper setting of controls. | Check and reset the controls. |
| | Heat exchanger areas caked with carbon and slag. | Clean heat exchanger areas. |
| Excessive Electrical | Fire may be set so low that burner operates continuously to heat the building. | Increase the GPH to proper size. |
| | Bad adjustment, low $CO_2$. | Adjust burner for proper $CO_2$ |

Inspection and Maintenance

The heating specialist is responsible for the inspection and maintenance of oil burners. Unless a heating specialist has the proper tools, he cannot perform maintenance as required. Several items are a must for servicing gun-type burners, and they are listed as follows:

- A pressure gauge set made up of 150-pound capacity pressure gauge, the fittings to connect it, and the petcock used for purging air from the oil line when starting the burner.

- A full set of Allen wrenches for turning setscrews, bypass plugs, and for adjusting the nozzle holder and electrodes. Only a socket wrench of the proper size is used for the nozzle. An open-end S-wrench is required for nozzle holders.

- A small thermostat wrench is packed with some thermostats and this is used for adjusting the differential.

- Be sure that the pipe dope used is for oil lines. If there is any doubt, order a can of special oil pipe dope and use it on all male pipe threads.

- A complete assortment of nozzles is needed. From the standpoint of time, it is cheaper to change a nozzle than to clean it on the job. After a few nozzles are accumulated, they should be cleaned in the shop.

  Nozzles should only be cleaned on a clean workbench kept in the shop. The nozzle is a delicate device and should be handled with care. A safety solvent is used to cut away the grease and gum and compressed air, if available, is used to blow out dirt. Goggles should be worn to protect the eyes when compressed air is used to remove dirt from the nozzle. Never use a metal needle to clean the orifice, sharpen the end of a match to use or use a brush bristle for this purpose. Always use a socket wrench when turning a nozzle. Be sure that the nozzle seat is clean. When the nozzle comes to the "bottom," back it off and retighten it several times to make a light oil seal. Do not tighten it too much or the brass threads will strip and make the removal of the nozzle difficult.

When installing either the pump or the motor, make a check as you put on the coupling to see that there is no ulndue pressure on the pump shaft. If there is excessive pressure, the coupling should be applied closer to the body of the fuel unit shaft.

## SUMMARY

The satisfactory performance of any type oil burner depends upon the proper installation, operation and maintenance of the unit. It is, therefore, recommended that the manufacturer's instructions for these services be procured for each oil burner at an installation.

## QUESTIONS

1. How are oil burners classified?

2. What are the different types of industrial oil burners?

3. How does a mechanical oil burner atomize the oil?

4. What are the three main parts of the horizontal rotary oil burner?

5. How does a horizontal rotary oil burner atomize the oil?

6. What is the purpose of the flexible coupling on a gun-type oil burner?

7. What holds the fuel tube and electrodes in place inside the blast of a gun-type oil burner?

8. What information will be stamped on the outside of the nozzle used in the gun-type burner?

## REFERENCES

AFM 85-12, Volume I and II, Operation and Maintenance of Central Heating Plants and Distribution Systems., Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization.

# OIL FIRED SPACE HEATERS

## OBJECTIVE

Upon completion of this lesson, you will be able to determine step-by-step procedures for removing, installing, and maintaining oil space heaters.

## INTRODUCTION

The earliest forms of house heating were all direct. They included the open fires with which primitive men warmed their dwellings. Some types of stoves and braziers (a pan for holding burning coals) that were adopted by the Romans are still used in various parts of the world. In the colder portions of Europe, the fireplace was developed as a method for heating rooms by means of an open fire. The first fireplaces were hearths recessed into the walls of buildings, with short flues. Fireplaces with high chimneys, which rose above the roof of the building and which provided adequate draft to keep the fires on the hearth burning brightly, were introduced during the 12th century. Fireplaces of today consist of a hearth closed on three sides with brick and a completely enclosed chimney or flue which carries away the smoke and combustion products of the fire.

The useful heat, given off by a fireplace, consists of the heat radiated directly by the burning fuel and that which is absorbed and re-radiated by the side and back walls. From 80 to 90 percent of the burning fuel is lost in the combustion gases and smoke which go up the chimney. The addition of fireplaces in modern houses is for beauty and style rather than for thermal efficiency.

In this section, we will discuss types of oil fired space heaters that are more efficient heat producers than the fireplace. We will also study the installation, operation and maintenance of these heaters. You may be called upon at any time to install, operate or maintain any one of these various types of space heaters. When you do have such an assignment, your supervisor will expect you to have a working knowledge of the type and of the fuel required to operate the heater. By gaining the knowledge contained in this section, you will be able to better understand the construction, operation and maintenance of the more complicated heating equipment you will use throughout your Air Force career.

## INFORMATION

A space heater--or stove, as it is sometimes called--is an enclosure of metal or ceramic materials where fuel is burned to provide heat. It is an improvement over the fireplace because its radiating surface is relatively larger and in contact with the air of the room, and because it gives a certain amount of heat by air convection. An efficient modern space heater utilizes about 75 percent of the heat of the fuel burned in it. In rural areas of the United States and many other parts of the world, space heaters are still being used extensively for heating houses. The fuels burned in these types of heaters include wood, coal, coke, peat, oil and gas.

Since the space heater is not a permanent installation, it can be located in a desirable place in the center of a room to provide the greatest amount of heat. However, the space heater is not very satisfactory in providing comfortable heat for a large space, because of its unique method of limited heat distribution. Even so, the simplicity of construction, the small initial cost, land the low rate of fuel consumption--regardless of whether it is coal, gas or oil--make the space heater desirable for heating small areas.

### Types and Applications of Oil Fired Space Heaters

Oil-fired space heaters are very simple in construction. They consist of a burner, a combustion chamber, an outer casing, a fuel tank and a fuel control valve. An air space is provided between the combustion chamber and the outer casing. Air that enters through grilles in the bottom of the heater is heated and then passes out through the grilles in the top of the unit.

Some oil-burning heaters are equipped with a blower and electric motor that force the heated air into the room. The units turn at slow speeds and are either direct-drive or belt-driven.

Oil-fired space heaters have atmospheric vaporizing-type burners, two of which we describe next. These burners require a lightweight grade of fuel oil (generally No. 1 weight) that vaporizes readily at low temperatures and leaves only small amounts of carbon and ash. The two types of oil-fired space heaters commonly used are the Blue Flame type and the natural draft pot-type.

## Construction Features and Controls

Blue Flame Type. The blue flame type burner is shown in figure 5-1. It includes a metal base formed of two or more circular fuel-vaporizing grooves and alternate air channels. Also included are several pairs of perforated sleeves or cylinders; one is inside, the others are mounted on the metal base. Each pair of perforated sleeves forms a combustion chamber above its grooves. One or more cover plates that rest on top of the nested cylinders baffle the flame and close the air passage. This forces the air through the perforations into the oil vapor chamber. In this way, a large number of air jets are introduced into the oil vapor, producing a good fuel mixture. The mixture burns with a clean, odorless blue flame.

These burners usually have a short asbestos kindling wick for ease in lighting. Some burners have a cup installed below the base so that alcohol can be burned to provide heat for starting. The wick and the alcohol are used only for lighting.

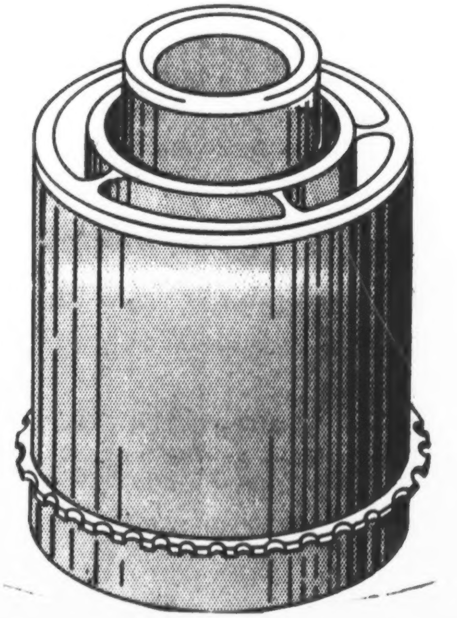


Figure 5-1. Blue Flame Oil Burner

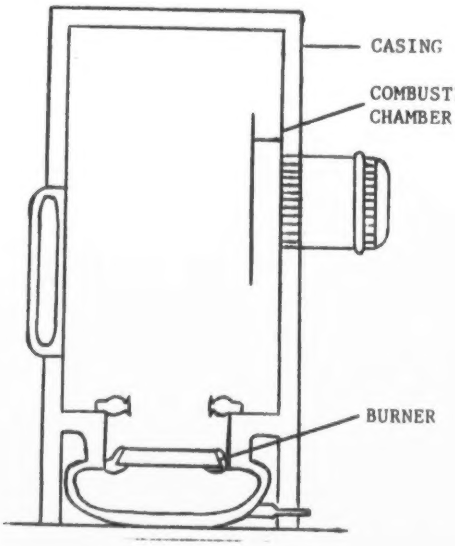


Figure 5-2. Cutaway Natural Draft Pot Type Space Heater

Natural Draft Pot Type Burner. Natural draft pot type distillate burners are widely used for space heaters (room heaters), wall heaters, floor heaters, water heaters, etc. They account for approximately 90 percent of all oil space heaters in use. The natural draft pot type space heater is composed of three main parts. (See figure 5-2)

Burner (Retorts). The burner (sometimes called retorts) may be of various shapes, rectangular or round, and designed with perforations (holes) in the shell which allow primary air to enter the combustion chamber and mix with the oil vapor. Figure 5-4.

A cutaway is shown in figure 5-3. In operation the distillate (oil) is fed at the bottom of the burner and is vaporized at this point by radiant heat from above. The vapors rise and mix with the air drawn through the perforated holes in the burner. During high fire conditions, the flame burns above the top combustion ring, as in figure 5-4.

NOTE: The oil level in the burner pot should not exceed 1/8 inch.

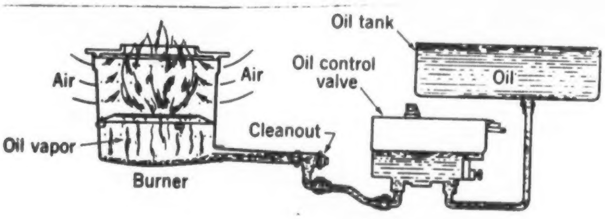
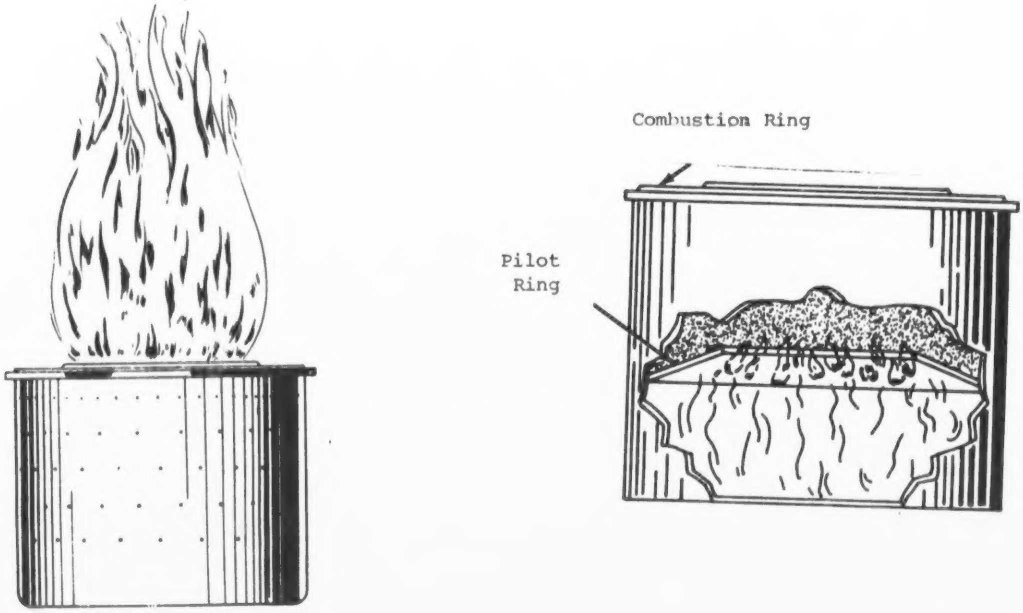


Figure 5-3. Natural Draft Pot Type Burner



High-Fire Flame

Figure 5-4. Flame Locations

COMBUSTION CHAMBER. The burner is located inside and at the bottom of the combustion chamber. The combustion chamber is heated by the flame in the burner and radiates the heat to the surrounding air.

CASING. The casing provides an air space around the combustion chamber. Air, that is to be heated, enters through grilles at the bottom of the casing. The air is heated and rises through grilles at the top of the casing. The casing will also provide protection against direct contact with the combustion chamber. Figure 5-2.

## Fuel Oil Control Valve

The oil control valve is the only safety device on the oil-fired space heater. The purpose of the oil control valve is to meter a precise amount of fuel oil to the burner pot.

The parts of the oil control valve consist of a strainer, reset lever, inlet needle valve, oil temperature compensating float, manual control knob, metering stem and guide assembly, and the safety tripout float.

Figure 5-5 illustrates a cutaway of an oil control valve and identifies component parts.

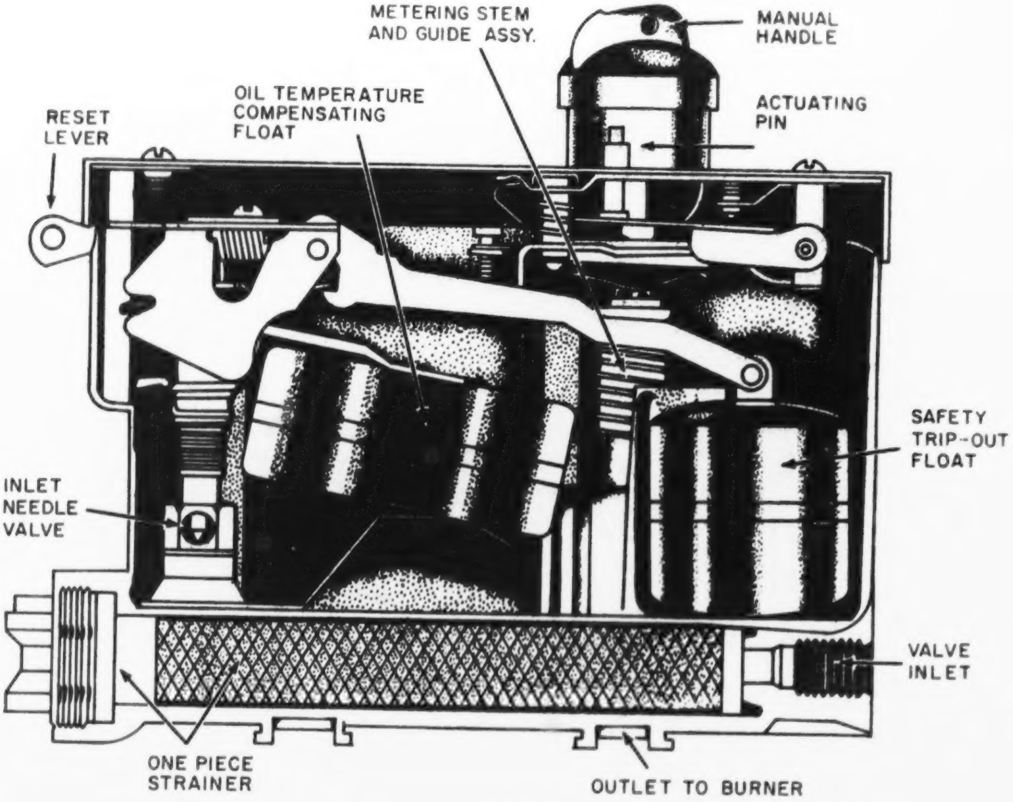

METERING STEM
AND GUIDE ASSY.
MANUAL
HANDLE
OIL TEMPERATURE
COMPENSATING
FLOAT
RESET
LEVER
ACTUATING
PIN
SAFETY
TRIP-OUT
FLOAT
INLET
NEEDLE
VALVE
VALVE
INLET
ONE PIECE
STRAINER
OUTLET TO BURNER

Figure 5-5. Fuel Oil Control Valve

The strainer prevents any impurities in the fuel oil from entering the oil control valve. (See figure 5-5) The inlet needle valve stops and starts the flow of oil to the valve and during operation is controlled by the oil temperature compensating float. The purpose of the oil temperature compensating float is to maintain a specific and constant amount of oil within the valve. The reset lever is a manual safety built into the oil valve. During periods the heater is not in operation, the reset lever is in the up position. This puts pressure on the inlet needle valve and holds it in the closed position so that no oil will enter the valve. During operation of the heater, the reset lever must be in the down position. This removes the pressure from the inlet needle valve and allows oil to flow to the valve. The manual control knob, located on top of the oil control valve, is the adjustment for the oil flow rate. The valve is calibrated to allow so much oil to pass through on low fire and high fire, and the different setting of the control knob will either increase or decrease oil flow rate somewhere between the low and high fire setting. As the control knob is turned from the low position to the high position, it raises the metering stem allowing more oil to flow through to the burner. The safety tripout float is an automatic safety which will trip the reset lever, closing the needle valve and stopping oil flow into the valve. The safety tripout float is actuated by high oil level within the valve. This safety device will provide 100 percent shutoff of oil in case of high oil level within the valve.

The most important part of the oil control valve, even though it has nothing to do with the operation, is the nameplate (see figure 5-6), mounted on top of the valve. On this nameplate is the manufacturer's name, operating instructions and the maximum and minimum flow rates (for calibration purposes) which are stamped on the plate in cubic centimeters per minute (which is the measurement used for calibration). This nameplate should be mounted on the valve at all times except when performing maintenance on the valve.

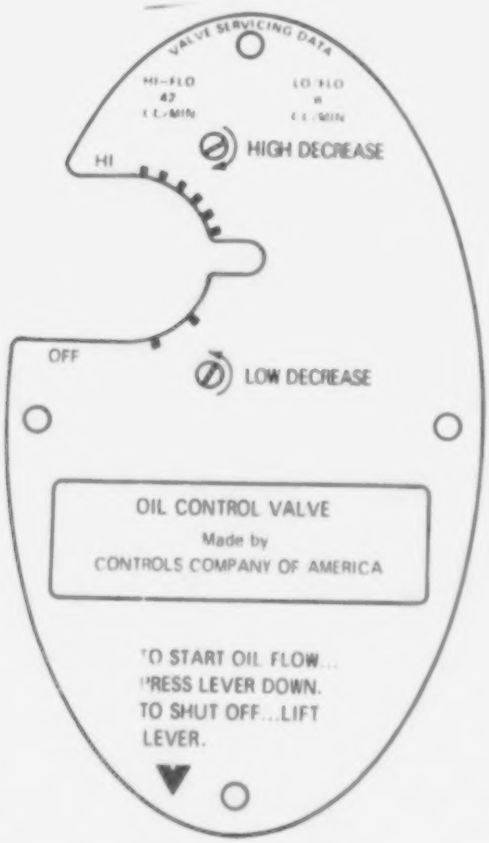


Figure 5-6. Oil Control Valve Nameplate

### Procedures for Removing, Disassembling and Reassembling

The variety of oil space heaters manufactured in the United States makes it difficult to state exact procedures for removing, disassembling and reassembling. Manufacturer's instructions for this type of work will be sent with the space heater. These instructions should be kept in the heating shop and followed whenever the need arises to perform these duties.

## Procedure for Inspecting and Cleaning

### Inspecting and Cleaning

SERVICES. Some of the more common services that should be performed on pot and blue flame type space heaters during preventive maintenance are listed below. These services should be performed as per AF regulations, manufacturer's specifications or local directives, to insure proper operation of the burners.

--Remove soot and carbon from heater exchangers, flues and chimneys.

--Remove soot and carbon deposits from the burners.

--Ream and clean out oil inlet.

--Clean the strainers in oil supply line.

--Clean the oil storage tanks.

## Procedures for Installing and Maintaining

Oil burning heaters are portable and are easily moved from one location to another. For satisfactory operation, follow the installation procedures supplied by the manufacturer. In both blue flame and pot type burners, oil is fed to the burner under control of a float-operated metering valve. Set the unit level so the oil can be properly distributed in the burner.

Since the oil level control valve is an important part of the space heater, it is necessary for it to function properly. For satisfactory results and uninterrupted service, give regular, periodic attention to its maintenance.

--Keep the valve clean. Do not let dirt or water accumulate on or in the valve. Clean the screen regularly.

--Keep the oil clean. Do not let dirt and water mix with the oil. Make sure oil tanks are clean before they are filled.

--Do not abuse the valve. Never use the valve assembly as a handle to lift the heater.

--Before servicing the oil level control valve, make sure the oil supply is cut off.

--Assure that the valve is properly leveled to prevent the floats from sticking. Level valve both end to end and side to side.

### Troubleshooting Oil-Fired Space Heaters

Some of the more common troubles encountered when troubleshooting pot and sleeve type oil-fired space heaters are in the following charts:

LOW OIL FLOW

| CAUSE | REMEDY |
|---|---|
| Air trapped in the oil supply lines. This condition may be caused by a combination of air leaks and high points in supply line. | Eliminate the high points in the piping and bleed the line. |
| The oil control valve may not be level. | Level the valve |
| Oil may be too heavy. | Use the grade of oil recommended by the manufacturer. |
| Dirt in oil supply line. | Clean the supply line. |

## LOW OIL FLOW

| CAUSE | REMEDY |
|---|---|
| Clogged oil strainer. | Clean strainer. |
| Dirt in metering mechanism. | Clean metering mechanism. |
| Sludge clogging supply line. | Clean supply line. |
| Fuel inlet clogged with carbon. | Remove carbon. |

## BURNER GOES OUT

| CAUSE | REMEDY |
|---|---|
| Check oil supply. | Add oil if necessary. |
| Plugged vent on oil supply tank. | Clean vent. |
| Insufficient oil flow. | Troubleshoot for low oil flow. |
| Improper fuel. | Use fuel recommended by manufacturer. |
| Fuel inlet plugged. | Clean fuel inlet. |
| Dirt in oil control valve. | Clean valve. |
| Oil valve not level. | Level valve. |
| Filter cartridge plugged with sludge and dirt. | Clean filter. |
| Excessive chimney draft. | Check proper operation of draft regulator. |
| Excessive flue downdraft. | Modify chimney height as required. Install downdraft hood. |

## BURNER IS FLOODED

| CAUSE | REMEDY |
|---|---|
| Stop oil flow. | Shut off main oil supply valve. |
| Drain fuel from burner. | Place a pan under the cleanout pipe, remove plugs, drain and replace the plug. |
| Light burner. | Practice safety. |
| Start oil flow. | Turn on main oil supply valve. |
| Operate burner. | Check for malfunctions which might have extinguished the flame. |

## HIGH FUEL CONSUMPTION

| CAUSE | REMEDY |
|---|---|
| Improper fuel. | Use fuel recommended by manufacturer. |
| Heat loss. | Reduce supply of air to burner. |

### HIGH FUEL CONSUMPTION

| CAUSE | REMEDY |
|---|---|
| Heat exchanger areas caked with carbon and slag. | Clean exchanger areas. |
| Excessive chimney draft. | Check operations of draft regulator. |

### Procedures for Operating and Adjusting the Oil Space Heater

When the oil control valve is opened, oil enters the burner at the bottom of the pot. A torch is used to light the oil. As it begins to burn, it vaporizes and the vapors rise and mix with the air entering through the perforations in the side of the pot.

The position of the flame within the burner depends on the amount of vapor produced, and the amount of vapor produced depends on the oil level in the pot. When large quantities of oil are vaporized, the flame stands in the pot. When large quantities of oil are vaporized, the flame stands high on the top ring as shown in figure 5-7A. Vapor travels to this point before enough air is mixed to produce complete combustion at this too high of a firing rate. At high firing rate, the flame is as shown in figure 5-7B. A minimum or low fire, the flame is as shown in figure 5-7C.

Figure 5-7D shows the effect if oil flow into the pot is too low. Vaporization and combustion take place on the bottom of the bowl. Air to support this combustion enters above the lower ring. Good mixing of air and vapor is not possible and the flame produced is smoky. Soot is deposited rapidly under these conditions and can foul heter and flue pipe so heavily that good operation is impossible. If combustion occurs below the lower ring, except in starting, oil flow rate is insufficient. In this case, increase oil flow rate or shut off heater entirely. If flame stands too high above burner or extends into the flue pipe, rate of oil flow is too great. In this case, decrease rate of flow to prevent dangerous overfiring.

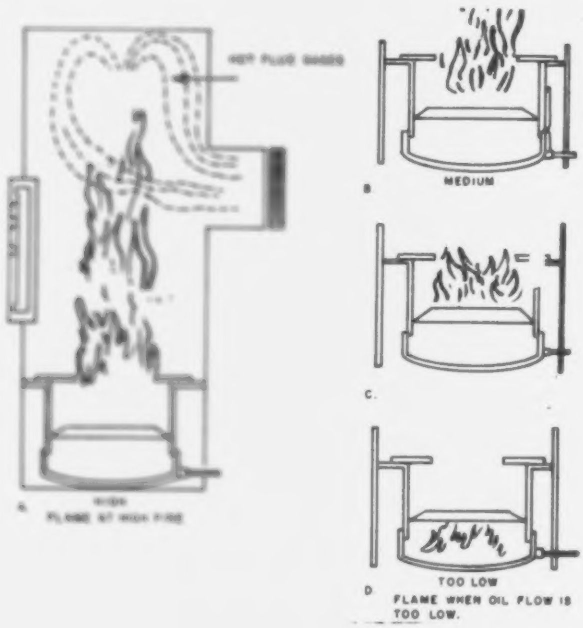


Figure 5-7. Position of Burner Flame at Different Rates of Fuel Flow

Since the flow of air to vaporizing type burners depends on the chimney draft, pay careful attention to this feature. Poor draft will result in a smoky flame that produces little heat, while a downdraft will make it almost impossible to keep the flame going at all.

The draft in a chimney is created by the difference in weight between the hot air or gases on the inside of the chimney, and the cold air on the outside. Hot air always rises. The hot gases produced by the combustion will rise in the chimney, causing cold air to be drawn into the space heater to replace it. This continuous action of the hot air rising in the chimney, and being replaced by cold air through the stove or space heater, is known as "draft." In cold weather, the draft may be stronger, due to colder air outside the building; whereas in summer, the draft is less due to smaller difference in the temperature (and weight) outside the building and inside the chimney.

Downdraft Hood

Often times, a downdraft is created by either a high tree or any adjacent taller building as illustrated in figure 5-8. In each of these cases, a downdraft hood will eliminate this condition.

In this case, the chimney is too short and when the wind blows from the opposite side of the house, a downdraft is created in the chimney. The height of the chimney should be increased to approximately three feet above the ridge of the house or install an approved downdraft hood on top of the present chimney.

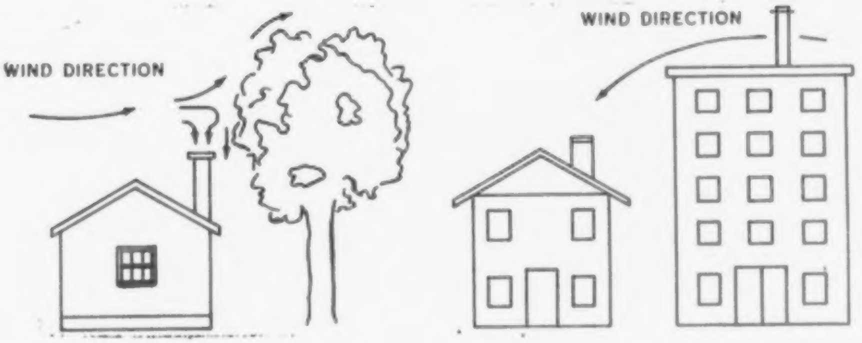


Figure 5-8. Causes of Downdraft

Downdraft may seriously interfere with properly functioning burners. Downdraft may result when the chimney is not high enough for the building roof line or is too close to other high buildings, trees or terrain features (figure 5-8). The chimney must be at least three feet above the highest point of the building roof. If the difficulty is caused by other factors, a downdraft hood may prove effective. Two types of downdraft hoods are the "A" and "H" type. Figure 5-9 illustrates an "H" type hood.

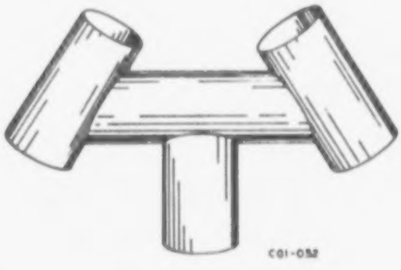


Figure 5-9. "H-Type" Hood

An automatic type of damper is usually installed in the first joint of the stovepipe where the pipe leaves the heater. It is a weighted butterfly damper that maintains a constant draft, regardless of wind and temperature. For this reason, it is usually called a "draft regulator" instead of a damper. An illustration of a draft regulator is shown in figure 5-10.

Automatic and proper operation of a draft regulator depends upon correct installtaion, because it must balance correctly and be free to move at the slightest change in draft pressure. Regardless of whether the regulator is installed in a vertical, horizontal or angled smokestack, the top of the damper must be at the true top position. The face must be plumb (straight up and down). When the regulator is used in a horizontal or nearly horizontal pipe, the counterweight is not used.

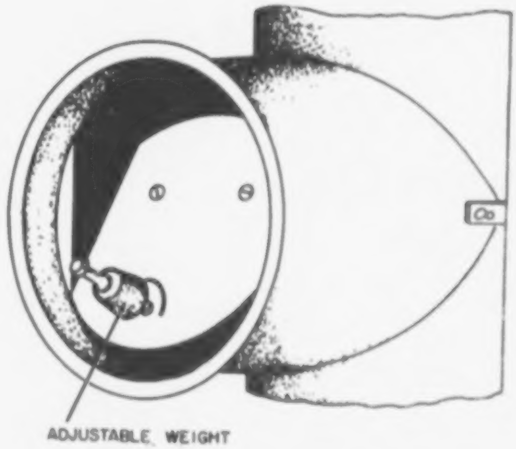


Figure 5-10. Draft Regulator

SUMMARY

Oil-fired heaters are ordinarily used when gas is not available. Oil can be transported into areas where gas and coal cannot. They are clean operating and do not require as close attention as coal stoves. Two types of burners are commonly used as oil-fired heaters. One type is a blue flame type burner and the other is the natural draft pot burner. In both types, lightweight fuel oil is fed into a bowl at the bottom of the burner where it is ignited by a wick. After ignition, the heat of combustion causes the oil to vaporize. Air mixes with the vapors and burning takes place at a point above the oil bowl itself. In order to avoid a smoky flame, oil-fired heaters require careful adjustment of the draft. Usually, an automatic draft regulator is used in the smoke pipe in place of a damper.

QUESTIONS

1. What are the two types of oil-fired space heaters?

2. What device is incorporated in an oil-fired space heater to maintain a constant draft?

3. What type of oil-fired space heater uses a kindling wick or alcohol cup for ignition?

4. What causes the oil to vaporize in an oil-fired space heater?

5. What determines the height of the flame in an oil-fired space heater?

6. Where is the draft regulator installed?

REFERENCES

1. Domestic and Commercial Oil Burners, third edition, by Burkhardt
2. ASHRAE Guide and Data Book, Equipment 1972

WORKBOOKS

J3ABR54532 001-III-1 thru III-5

# Technical Training

# Heating Systems Specialist

# CONTROLS, TROUBLESHOOTING AND OIL BURNERS

MARCH 1983

3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

DESIGNED FOR ATC COURSE USE
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ATC FORM 214 (JAN 76) OBSOLETES ATC FORMS 214, MAY 69, 522, NOV 63 AND 523, MAY 71. STANDARD COVERSHEET

This workbook contains practical work assignments for you to accomplish in conjunction with your study assignments. Complete each problem or work assignment in the sequence given and it will aid you in understanding and retaining the key points covered in each assignment.

## TABLE OF CONTENTS

## WORKBOOKS J3ABR54532 001-III-1 thru III-5

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# ELECTRICAL AND ELECTRONIC CONTROLS

## OBJECTIVE

When you have completed this workbook, you will be able to:

-- Explain facts about the purpose, use and principles of operation of electrical controls.

-- Adjust electrical controls to assure proper operation.

-- Identify basic facts relating to electronic controls.

-- Explain facts about the theory of operation and use of pneumatic controls.

-- Explain basic facts about troubleshooting pneumatic controls and equipment.

## PROCEDURE

### EXERCISE 1

### Adjust Electrical Controls

CAUTION: Observe safety precautions when working with electricity.

NOTE: Remove all watches, rings, and other jewelry.

1. Locate thermostat.
2. Disconnect electrical power from furnace.
3. Locate Primary Control and note current draw.
4. Adjust heat anticipator to current draw of Primary Control, or as per instructions of instructor.
5. Have instructor check work.

### EXERCISE 2

### Electrical Controls

1. A control that can only be placed in the on/off position is an example of a ________ control.

2. A ____________________ is a temperature sensing device that responds to changes in ambient temperature.

3. A thermostat can operate by ________________ or ________________ voltages.

4. What control should stop the burner in case of excessive temperature?

________________________________________________________________

5. A fan switch is used to control the ____________________.

6. When using the Bimetallic strip what causes it to bend? ____________________

____________________________________________________________

7. What causes the liquid to gasify in the compressible type bellows?

____________________________________________________________

8. What is the purpose of capillary tube on the remote-bulb device?

____________________________________________________________

9. Name the two types of pilotstats. ____________________

____________________________________________________________

10. Explain the operation of thermoelectric pilotstat when the pilot flames goes out.

____________________________________________________________

____________________________________________________________

____________________________________________________________

11. The valve type pilotstat will shut the gas off to the __________ and ________ in case the pilot flame is extinguished.

12. The contacts on a limit control are normally ____________________.

13. The normal temperature range for the limit control is __________ to __________.

14. The primary control for gas is a simple switching device which ______________ and ________________ the main circuit.

15. Three types of automatic gas valves are __________, ____________, __________.

16. What is the primary control for gas burners? ____________________

____________________________________________________________

17. Which primary control incorporates four controls? ____________________

____________________________________________________________

18. The fan ON setting is usually __________ to __________ above the fan OFF setting.

19. S.G., Figure 1-19. What control device operates on low voltage?

____________________________________________________________

20. S.G. Figure 1-20. The gas valve operates on __________ voltage.

# ELECTRONIC CONTROLS

1. Why do we use electronic controls? ______________________________

______________________________________________________________

2. What are electronic controls used for? ______________________________

3. What is the purpose of flame safeguard protection? ______________________________

______________________________________________________________

4. Why do large boilers use programmers? ______________________________

______________________________________________________________

______________________________________________________________

5. What are electronic "sensors"? ______________________________

______________________________________________________________

6. Electronic flame safeguard sensors respond to __________ or __________ light or __________ __________ ______________.

7. What was the first electronic flame sensor? ______________________________

8. How does a cadmium cell sense visible light? ______________________________

______________________________________________________________

9. Explain how the lead sulfide cell senses light. ______________________________

______________________________________________________________

10. What does the ultraviolet sensor sense? ______________________________

## PNEUMATIC CONTROL SYSTEMS

1. What are pneumatic controls used for?

2. How often should the air storage tank be drained of water?

3. What is the purpose of the pressure reducing valve?

4. Air piping and distribution systems for pneumatic controls consist of ____________ and ____________________________.

5. What type of automatic control system has continuous feedback?

6. What is the usual pressure of supply air?

7. What controls the pressure in the air supply tank?

8. What is the purpose of the supply air lines?

9. How often should the oil in the pump crankcase be changed?

10. How often should motor be oiled?

11. Define the term pneumatic controls.

12. How are pneumatic controllers classified?

13. What type of pneumatic controller produces a gradual action of the controlled device?

14. Mediums that affect the space or room conditions are called __________ _________.

15. The ______________ _______________ is the final contact element that is activated by the control pressure.

# TROUBLESHOOTING OF ELECTRICAL CONTROLS

When you have completed this workbook, you will be able to:

-- Using the step-by-step procedures, troubleshoot electrical controls on a warm air furnace trainer with instructor assistance.

-- Trace electrical circuits, isolate electrical malfunctions and perform minor repairs to electrical circuits.

PROCEDURE

## EXERCISE 1

## Troubleshooting a Warm-Air Furnace Low-Voltage Control Circuit

CAUTION: Remove all jewelry; make sure power is OFF before wiring the trainer. Check wiring leads for damage.

Working on trainer provided, troubleshoot and identify faulty heating controls in a low-voltage warm-air furnace control circuit.

1. Obtain multimeter from supply cabinet.

2. Obtain wiring leads from trainer drawer.

3. Wire the low voltage trainer, using figure 1 of this workbook as a guide.

4. Have the instructor check your circuit before energizing and lighting the pilot.

5. Apply power to the trainer, light pilot and check circuit for normal operation.

6. Thermostat --

   a. Adjustment - Heat Anticipator

      (1) Adjust heat anticipator to match the current rating of the primary control (gas valve), which is usually stamped on the control nameplate.

      NOTE: If the current rating is not given for the primary control, use the manufacturer's specifications.

      (2) Move the indicator to match the rating of the primary control, and the heat anticipator will be properly adjusted.

      NOTE: The indicator may be moved with fingers, pencil point or pin.

7. Combination Control (Fan - Limit Switch)

   a. Calibration -- None.

   b. Adjustment --

   NOTE: On the dial or face of the combination control are temperature settings for the fan and limit switches. The dial has a temperature range from 50°F to 250°F with 20 subdivisions, each worth ten degrees. Included also are three temperature indication pointers, two for the fan switch and one for the limit switch.

(1) Limit Switch -

(a) Remove cover.

(b) Locate temperature indicator pointer -- at the top of the dial.

CAUTION: Do not rotate dial. Hold dial firmly with fingers while positioning pointers.

(c) Using your fingers, position the pointer to the 200°F mark on the dial.

(d) The limit switch is now adjusted to prevent overheating and a possible fire hazard.

(2) Fan Switch -

NOTE: This switch has two temperature settings, identified by pointers. They are: the fan ON pointer which is below the limit switch pointer, and the fan OFF setting which is the lowest pointer on the dial.

CAUTION: Do not rotate dial. Hold dial firmly with fingers while positioning pointers.

(a) Using an ON temperature setting of 80°F, adjust the middle pointer to the given temperature located on the dial.

(b) Set the fan OFF pointer to maintain a differential of 15 to 25 degrees.

8. Have the instructor check your trainer.

NOTE: On the back of the trainer are trouble switches labeled 1 through 6. Start with trouble switch number 1, turn it to the ON position. Then troubleshoot the circuit using the multimeter to identify the faulty control. Enter the trouble in 9 below; when this is done, place the first trouble switch in the OFF position and proceed until all troubles have been identified.

9. Identify the six troubles you have found with your trainer and list them in order below:

TROUBLE

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

10. Have the instructor check your completed workbook.

11. Secure the pilot and power, then remove the wiring leads and return them to the trainer drawer.

12. Proceed to next trainer.

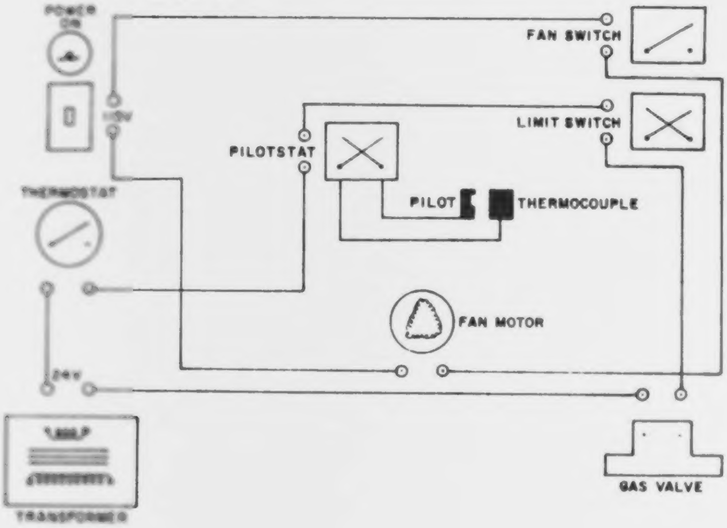

POWER ON
110V
FAN SWITCH
LIMIT SWITCH
PILOTSTAT
PILOT
THERMOCOUPLE
THERMOSTAT
FAN MOTOR
24V
TRANSFORMER
GAS VALVE

Figure 1. Warm-Air Furnace Low-Voltage Control Circuit

## Troubleshooting a Warm-Air Furnace Line-Voltage Control Circuit

CAUTION: Insure power is OFF before wiring the trainer. Check wiring leads for damage.

Working on trainer provided, troubleshoot and identify faulty heating controls in a low-voltage warm-air furnace control circuit.

1. Obtain wiring leads from trainer.

2. Wire the line voltage trainer using figure 2 as a guide.

3. Have instructor check your circuit before energizing and lighting the pilot.

4. Apply power to the trainer, light pilot and check circuit for normal operation.

   NOTE: On the back of the trainer are trouble switches labeled 1 through 6. Start with trouble switch number 1, turn it to the ON position, then troubleshoot the circuit using the multimeter to identify the faulty control. Enter the trouble in 5 below; when this is done, place the first trouble switch in the OFF position and proceed until all troubles have been identified.

5. Identify the troubles you have found with your trainer and list them in order below.

   TROUBLE

   a. ______________________________

   b. ______________________________

   c. ______________________________

a. ______________________________________________

b. ______________________________________________

c. ______________________________________________

6. Have the instructor check your completed workbook.

7. Secure the pilot and power, remove the wiring leads and return them to trainer drawer.

8. Proceed to next trainer.

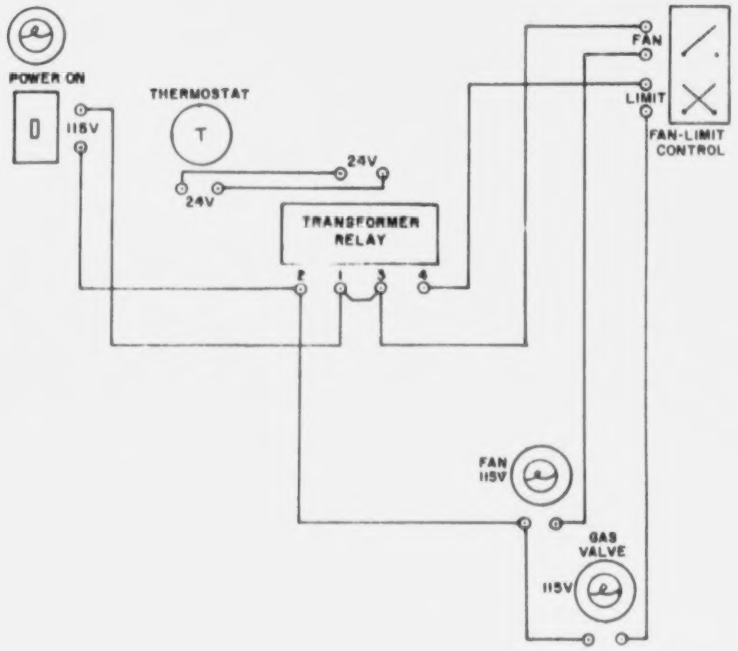

POWER ON
115V
THERMOSTAT
T
24V
24V
TRANSFORMER RELAY
2
1
3
4
FAN
LIMIT
FAN-LIMIT CONTROL
FAN 115V
GAS VALVE
115V

Figure 2. Warm-Air Furnace Line-Voltage Circuit

## Troubleshooting Hot Water Boiler Control Circuit

CAUTION: Insure power is OFF before wiring the trainer. Check wiring leads for damage.

Working on trainer provided, troubleshoot and identify faulty heating controls in a hot water boiler control circuit.

1. Obtain wiring leads from trainer drawer.

2. Wire the hot water boiler control circuit using figure 3 as a guide.

3. Have the instructor check your circuit before energizing and lighting the pilot.

4. Apply power to the trainer, light pilot and check circuit for normal operation.

NOTE: On the back of the trainer are trouble switches labeled 1 through 8. Start with trouble switch number 1, turn it to the ON position. Then troubleshoot the circuit using the multimeter to identify the faulty control. Enter the trouble in 5 below; when this is done, place the first trouble switch in the OFF position and proceed until all troubles have been identified.

5. Identify the eight troubles you have found with your trainer and list them in order below.

TROUBLE

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

h. ______________________________

6. Have the instructor check your completed workbook.

7. Secure the pilot and power, then remove the wiring leads and return them to the trainer drawer and return the multimeter to the storage cabinet.

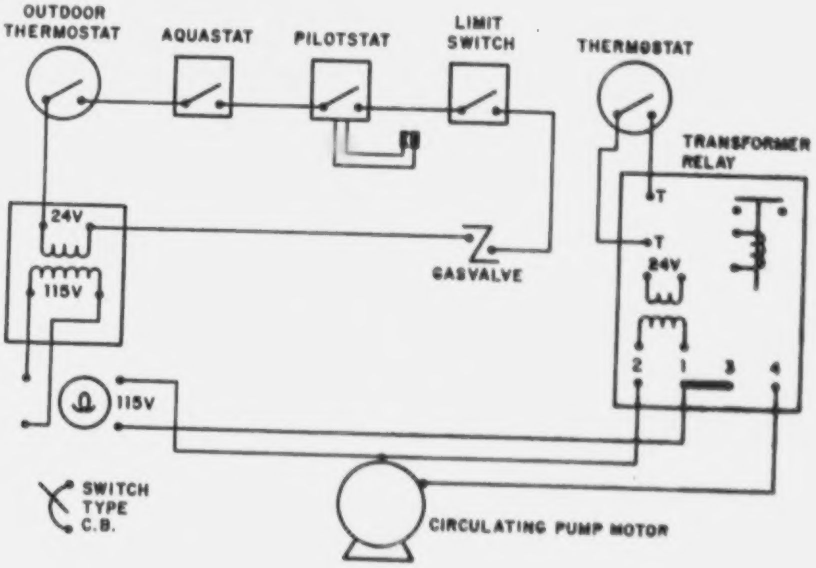

OUTDOOR THERMOSTAT
AQUASTAT
PILOTSTAT
LIMIT SWITCH
THERMOSTAT
TRANSFORMER RELAY
24V
115V
GASVALVE
T
T
24V
2
1
3
4
115V
SWITCH TYPE C.B.
CIRCULATING PUMP MOTOR

Figure 3. Hot Water Boiler Control Circuit

## EXERCISE 2

### Troubleshooting Heating Control Systems

1. List three types of electrical troubles.

   a. ______________________________

   b. ______________________________

   c. ______________________________

2. Define the types of troubles listed in the above question.

   a. ______________________________

   b. ______________________________

   c. ______________________________

3. Give three examples of an open.

   a. ______________________________

   b. ______________________________

   c. ______________________________

4. Give two examples of a short.

   a. ______________________________

   b. ______________________________

5. Define a cross short.

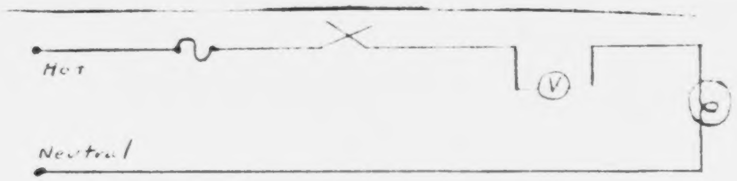
6. What is an indication of low power?

7. What meter is used to locate an open?

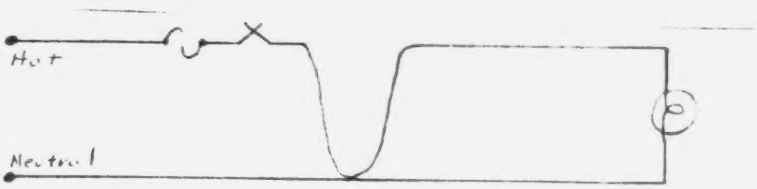
8. What is an indication of a direct short?

9. List four testers that can be used to locate an open.

10. The voltmeter placed in the circuit below will indicate ______________ volts.



11. The above diagram is an example of an ________________________.



12. The above diagram is an example of a _________________ __________________.

13. The exact location of an open can be found by using the __________________________.

14. What are two types of shorts?

15. Define the term infinite.

16. List the types of testers that should be used to locate a direct short.

17. When trying to locate a cross short with an ohmmeter the power must be ___________.

18. What testing device cannot be used in locating a cross short?

19. What is an effect of a shorted switch?

20. What maintenance is required for a shorted switch?

# COMBUSTION EFFICIENCY AND DRAFT

## OBJECTIVE

Upon completion of this workbook, you will be able to compute combustion efficiency.

## PROCEDURE

### EXERCISE 1

### Perform the Combustion Analysis and Compute Combustion Efficiency

CAUTION: Before entering boiler area, remove watches and rings. Observe safety precautions that apply when working with operating heating equipment.

1. Draw flue gas analyzer kit from supply cabinet.

2. Examine flue gas analyzer kit.
   a. Check rubber sampling tube and aspirator bulb for leaks.
   b. Insure adequate chemical liquid level.
   c. Insure kit is complete

3. Proceed to boiler area with instructor (Take WB and SG)

### Operation of Fyrite Analyzer

1. Draw a flue gas sample in accordance with the following procedures to determine $CO_2$ content.
   a. Invert analyzer to allow chemical solution to wet the inside surfaces of the analyzer; then turn upright to get fluid run back into the bottom reservoir.
   b. Hold analyzer upright and depress plunger valve. This action will vent the analyzer to atmosphere, releasing the previous flue gas sample.
   c. Zero the scale. Loosen the locknut in rear of scale and slide scale until the zero mark lines up with top of fluid column, then tighten locknut.
   d. Insert open end of metal sampling tube into the center of the flue gases to be analyzed, if at all possible.
   e. Holding the analyzer upright, lay the connector tip on the plunger valve at the top of the analyzer.
   f. Depress plunger valve with connector tip and squeeze and release aspirator bulb 18 times.
   g. After the 18th squeeze and before releasing the bulb, release the connector tip and plunger valve.
   h. To force the trapped flue gas sample through the chemical solution, invert the analyzer at a 45-degree angle and upright at a 45-degree angle three or four times. This will allow the fluid to run from the top reservoir to the bottom reservoir and vice versa.

i. Hold the analyzer upright or place on level surface for several seconds, so as to allow all the chemical solution to drain from the top land read the percent $CO_2$ on the scale.

2. The following Combustion Efficiency Graphs (figures 4 through 6) may be used to determine the combustion efficiency when burning the more common fuels. When using these graphs, it is necessary to know: first, the percentage of the $CO_2$ in the flue gas; second, the temperature of the flue gas; third, the room temperature; and fourth, the type of fuel being used. With this information, determine the combustion efficiency in the following manner:

   a. Find the difference between the flue gas (stack) temperature and room temperature. This is the net stack temperature.

   b. Locate, on the bottom of the scale, the point that represents the net stack temperature on the proper graph.

   c. Find the diagonal line which represents the amount of carbon dioxide in the flue gas.

   d. Find the point of interception of the two lines.

   e. Draw a horizontal line to the left-hand scale from where the two lines intercept. The point at which the horizontal line crosses the left-hand scale represents the percentage of combustion efficiency. See figure 4.

3. Determining Combustion Efficiency Using Fyrite Computer. After determining the percent of $CO_2$ present in the flue gas, the combustion efficiency can be determined by using this information, an efficiency finder computer, and following the procedure given below.

   a. Measure flue gas temperature with suitable thermometer prior to taking flue gas sample.

   b. Subtract room or air inlet temperature from the flue gas temperature to get a NET STACK TEMPERATURE.

   c. Insert the correct fuel slide into the efficiency finder computer.

   d. Set slide so net stack temperature appears in window of computer.

   e. Set arrow on cross-slide to percent $CO_2$ found in analysis and read percent combustion efficiency (black figures) or percent stack loss (red figures).

4. Using factors and graphs given in the workbook, compute percent combustion efficiency for the following (carry to one decimal place).

   a. Stack Temperature ______________________________

   b. Room Temperature ______________________________

   c. Net Stack Temperature ______________________________

   d. Type of Fuel ______________________________

   e. Percent of $CO_2$ ______________________________

   f. Percent Combustion Efficiency ______________________________

5. Have the instructor check your work.

Checked by ______________________________
Instructor

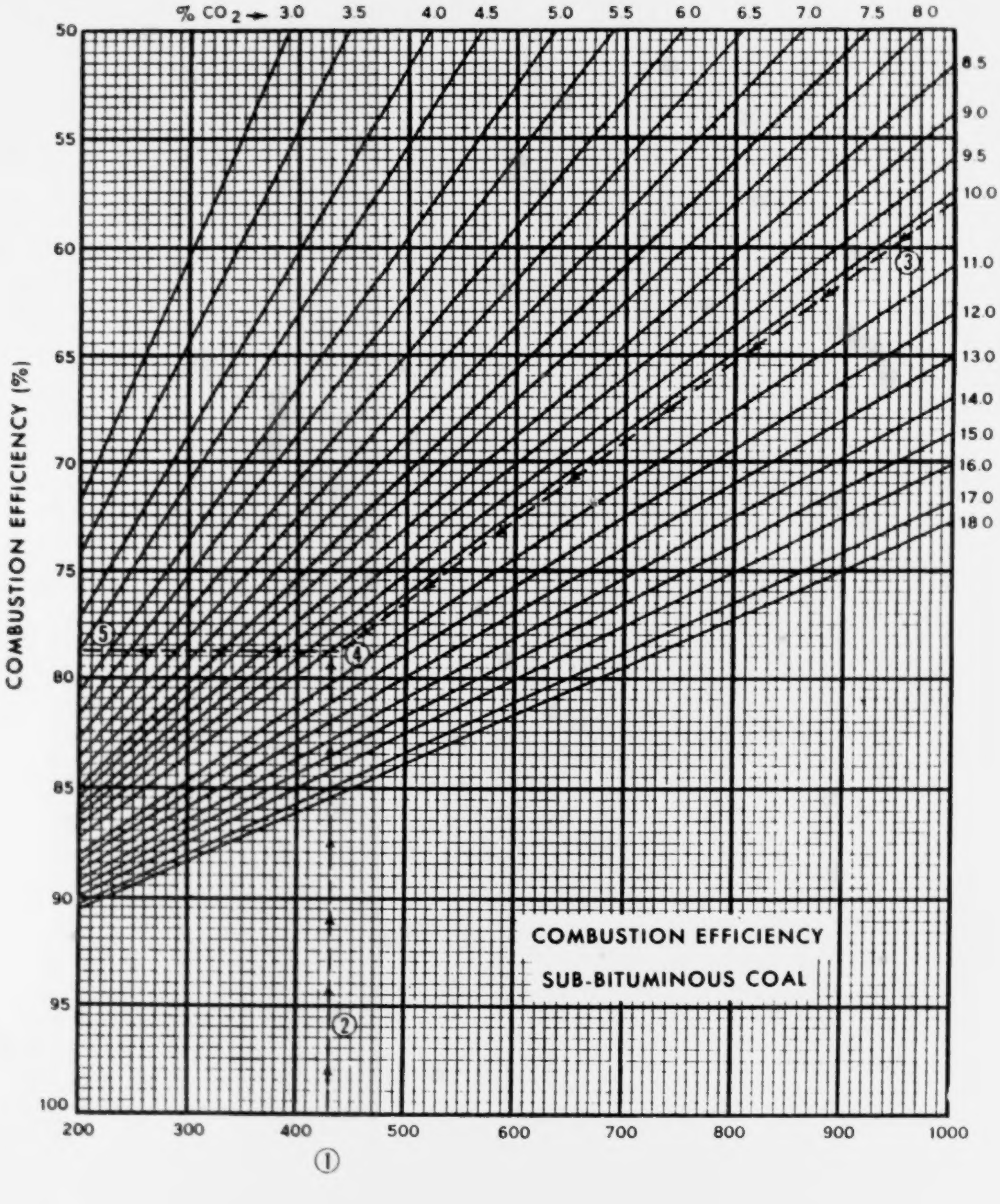


Figure 4. A Graph Used to Determine the Combustion Efficiency of a Heating System Firing with Subbituminous Coal

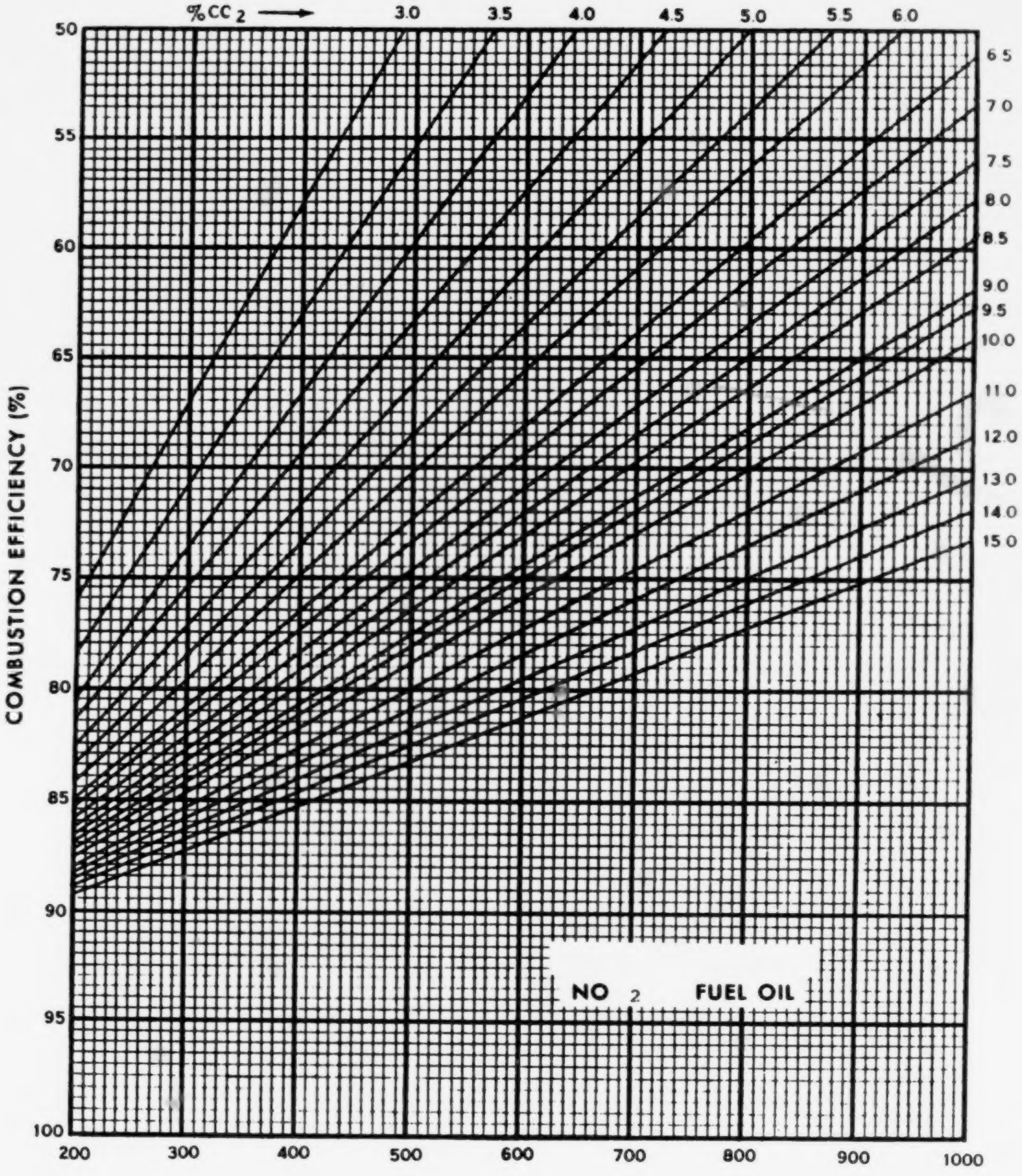


Figure 5. A Graph Used to Determine the Combustion Efficiency of a Heating System Firing with No. 2 Fuel Oil

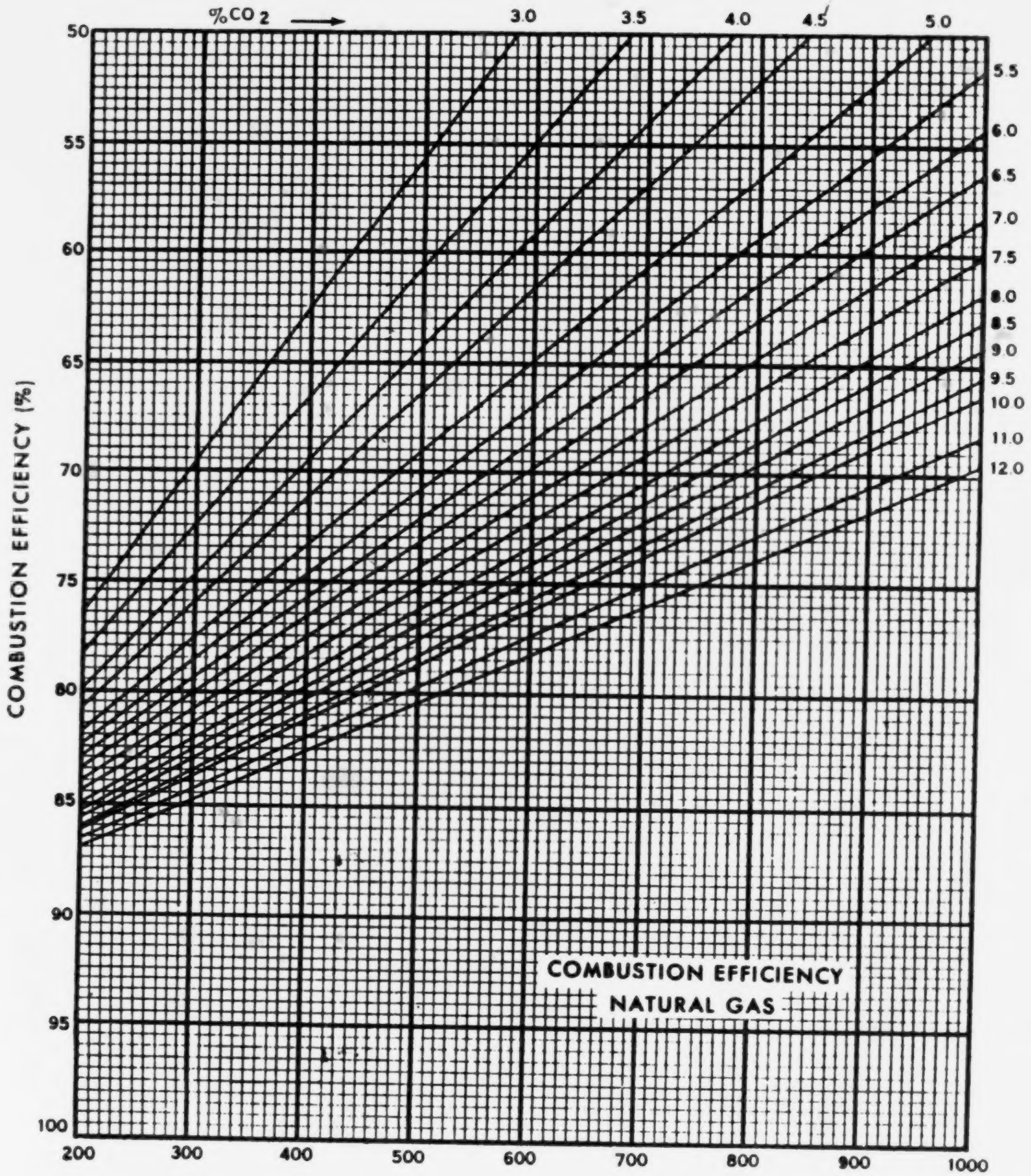


Figure 6. A Graph Used to Determine the Combustion Efficiency of a Heating System Firing with Natural Gas

## EXERCISE 2

### Combustion Efficiency and Draft

1. ____________________ ____________________ is the ratio of the useful heat delivered by the burning fuel to the supply of fuel.

2. Improper combustion efficiency causes ____________________________________.

3. What percent $CO_2$ is considered to be perfect combustion?

4. What gasses are produced in the combustion process?

5. What are the methods of combustion analysis?

6. What information must be known to be able to compute combustion efficiency?

7. What does the term "net stack temperature" mean?

8. What is meant by the term "usable" heat?

# DOMESTIC AND INDUSTRIAL OIL BURNERS

## OBJECTIVE

When you have completed this workbook you will be able to:

-- Explain the characteristics of oil.

-- Explain the theory of gravity and forced fuel oil supply systems.

-- Explain the theory of construction and operation of rotary pumps.

-- Explain the procedures used to install fuel oil piping systems.

-- Determine the quantity of fuel in storage tanks.

-- Explain the principles of operation of domestic and industrial oil burners.

-- Inspect, disassemble, clean and reassemble a warm air furnace and its controls.

## PROCEDURE

### EXERCISE 1

### Maintaining Oil Supply Systems

1. Oil Systems --

   a. Draw fuel tank dipstick, rags and hand tools.

   b. Proceed to work area with instructor.

   c. Check grounding on oil storage tank.

   d. Inspect system for loose fittings, leaking valves and corrosion.

   e. Tighten any loose fittings, repair or replace leaking valves, and replace any lines that are corroded.

   CAUTION: Observe safety precautions when performing duties around fuel storage tank and fuel lines. Do not use the top two rungs on the ladder. Have someone hold ladder. Use a ladder equipped with nonslip shoes. Remove watches and rings.

   f. Remove filler pipe cap and insert dipstick vertically into the fuel storage tank until the dipstick touches the bottom of the tank.

   g. Keeping the dipstick vertical, remove it from the fuel storage tank.

   h. Check the dipstick to find where liquid level of fuel is in inches. (Stick will be wet.)

   i. Check the dipstick to find where liquid level of fuel is in gallons.

   j. Enter amount of fuel in the spaces provided.

      (1) ________________ inches

      (2) ________________ gallons

## EXERCISE 2

### Domestic and Industrial Oil Burners

1. What are the two major classifications of fuel oil?

2. What does the term "viscosity" mean?

3. Why must an above ground storage tank have an electrical grounding strap?

4. For safety, a fill pipe must be ______ feet away from building openings.

5. Bulk fuel oil storage should not be entered without permission from ______________ ________________ for safety reasons.

6. Approved _______________ ______________ equipment will be used inside bulk fuel storage tanks.

7. __________________ is probably the most practical way to control static charges.

8. How full should a fuel oil storage tank be filled? Why?

9. What happens to the unused fuel oil when the single-pipe, gravity-feed, fuel oil supply system is used?

10. What happens to the excess fuel oil when the double-pipe, gravity-feed, forced-return oil supply system is used?

11. Why must extreme care be exercised when using the double-pipe, gravity-feed, forced-return oil supply system?

12. Maintenance of fuel oil piping systems consist of _______________ or ___________.

13. When should strainers be cleaned?

14. What is the purpose of piping strainers?

15. Rotary pumps used rotating ________, ________, ________, ________ or ______ to impart pressure to the liquid.

16. List the two commonly used rotary pumps.

17. Rotary pumps are ______________ ________________ pumps.

18. Always start a rotary pump with both ____________ ____________ valves open.

19. How are oil burners classified?

20. How does a mechanical oil burner break up the oil?

21. What type of oil burner uses steam or air to break up the oil?

22. What makes a horizontal rotary oil burner an ideal burner?

23. What are the three main parts of the horizontal rotary oil burner?

24. What are gun-type oil burners used for?

25. What is used to connect the fuel pump to the motor on a gun-type oil burner and what purpose does it serve?

26. When should you use a two-stage fuel oil pump?

27. What four functions does the nozzle serve on the gun-type oil burner?

28. What is a likely cause of a gun-type burner puffing upon start-up?

## EXERCISE 3

## Maintaining an Oil-Fired Warm Air Furnace

Using the following procedures, remove, dismantle, reassemble and install a warm air furnace located in the student performance area. Draw required tools from tool cabinet. Inspect the tools to insure good condition and correct numbers. Have unit checked by instructor after it has been disassembled. Assemble the unit and correct the electrical controls to the unit.

NOTE: Have instructor check before closing electrical switches.

### Removing, Disassembling, Cleaning, Adjusting, Reassembling and Operating an Oil-Fired Warm Air Furnace

| WHAT TO DO | HOW | CAUTIONS |
|---|---|---|
| 1. Make sure unit has been secured. | | |
| 2. Pull back transformer. | Loosen screws. | |
| 3. Disconnect wires | | White-Common; Black-Motor |
| 4. Remove flex conduit from burner. | Remove locking nut on conduit connector. | |
| 5. Disconnect fuel line from pump. | Use an open-end wrench of appropriate size. | Be careful of copper tube connectors; don't bend or cross thread. Make sure oil has been turned off. |
| 6. Remove burner. | Remove three nuts. | Do not spill oil from pump. NOTE: Take burner to workbench. |
| 7. Remove electrical controls, conduit and wiring. | Disconnect wires from controls, remove conduit locknuts. Remove conduit with wires, pull wires out of conduit and give the wires to the instructor. Remove combination control stack switch (if applicable), and burner mounted primary control (if applicable). | Controls will be used for wiring project. |
| 8. Remove stack. | Lay to side of furnace. | Do not disassemble the stack. |
| 9. Inspect and clean furnace and heat exchanger. | Check heat exchanger for corrosion and holes. | Use rags, foxtail or vacuum to clean. |

| WHAT TO DO | HOW | CAUTIONS |
|---|---|---|
| 10. Pull burner and inspect combustion chamber. | Use an open-end wrench of appropriate size. | If anything is found wrong, inform instructor. |
| 11. Remove transformer. | Test transformer using ohmmeter. | |
| 12. Disconnect oil line from pump to fuel tube. | Use line wrench of appropriate size. | Be careful of copper tube connectors; do not bend or cross thread. |
| 13. Remove fuel tube, electrode and nozzle assembly. | Loosen screw and pull out whole assembly. | Those burners with fire eye, slip fire eye to one side. |
| 14. Remove electrodes. | Loosen nut and release porcelain and pull back through deflector. | Do not remove screws; be careful not to damage PORCELAIN insulators. |
| 15. Clean electrode assembly. | Diesel oil or No. 2 fuel. Shine electrode tips. | Use a rag (silk preferred). No abrasives; carbon on porcelain will cause electrical shorts. |
| 16. Remove nozzle from adapter. | Two wrenches of appropriate size. | Using only one wrench will loosen adapter from fuel nozzle pipe. |
| 17. Disassemble and clean nozzle; remove strainer, remove nozzle stem and inspect. | Screwdriver and 5/8" boxend wrench, soak in diesel oil or No. 2 fuel oil, clean with soft wood or plastic. | Do not clamp nozzle in vise and crush tip. Do not use metal to clean nozzle, it might enlarge holes and distort slots. |
| 18. Assemble nozzle. Insert stem. Clean or replace strainer screen. | Hand tighten strainer screen. Use diesel oil or hot soap water and low pressure air. Cinch nozzle in place snugly. | Get small parts together. Stem must not be wedged into place or it will cut off the flow of oil. |
| 19. Clean nozzle adapter and nozzle pipe. | Swab out with diesel oil and rags. | Remove all lint; be careful not to damage threads. |
| 20. Replace nozzle. | Use TWO wrenches, turn clockwise. | Securely tighten in place. |
| 21. Replace electrodes. | Snap in electrode rods; hand tighten rod to procelain. Tighten screws in deflector lightly. | Electrodes must be able to move in order to be adjusted. |

| WHAT TO DO | HOW | CAUTIONS |
|---|---|---|
| 22. Adjust electrodes. | Move electrode so that tips be 1/8" apart and 1/2" above center of nozzle. Electrodes must extend out from nozzle. Tighten deflector screws. Tighten rods to porcelain. | Electrodes must not come in contact with the fuel oil spray. Distance these extend depends upon spray angle. Do not tighten deflector screws too tight and crack porcelain. |
| 23. Install fuel tube, nozzle and electrode assembly. | | If applicable, replace fire eye. |
| 24. Remove strainer from pump, clean and put back in. | Use an open-end wrench of appropriate size. | Use diesel oil or hot soapy water and low pressure air. Replace if necessary. |
| 25. Insert burner into combustion chamber. | Insert burner air tube into hole provided in combustion chamber, slide burner forward so end of air tube is flush with inside wall of firebox. | Make sure burner is level. |
| 26. Insert wires and install controls. | Follow wiring diagrams, refer to instructor for help. | All wire connections must be made with wire nuts. |
| 27. Install transformer. | | |
| 28. Connect electrical supply. | For wiring system, refer to instructor for help. | Insure electric source is that required by nameplate 110-volt ac, 60 cycle. |
| 29. Connect fuel supply. | With two open-end wrenches, connect flexible copper tubing fuel supply to inlet connection of fuel pump. | Do not cross thread fittings. |
| 30. Start burner with instructor present and observing operation. | Close electrical switch (circuit). Set the thermostat to call for heat. | Plug into electrical outlet. |
| 31. Perform combustion analysis. | Adjust sliding air shutter to establish a good flame. Using fyrite and combustion efficiency graphs. | Flame should be long and lazy if fire is raw or stringy--too much air; smoky, not enough air. |
| 32. Test operate. | Run burner a few minutes and visually check appearance of flame. | |

| WHAT TO DO | HOW | CAUTIONS |
|---|---|---|
| 33. Troubleshoot furnace control system. | As per instructions given by instructor. | |
| NOTE: Check controls by lowering thermostat setting, which will secure the burner Wait for fan switch to secure fan and then set thermostat to call again. | | |
| 34. Secure burner. | Turn down thermostat. | |
| 35. Secure electrical power. | Unplug unit. | |
| 36. Secure fuel supply line. | Close valve next to furnace. | Be sure oil supply pump is off. |

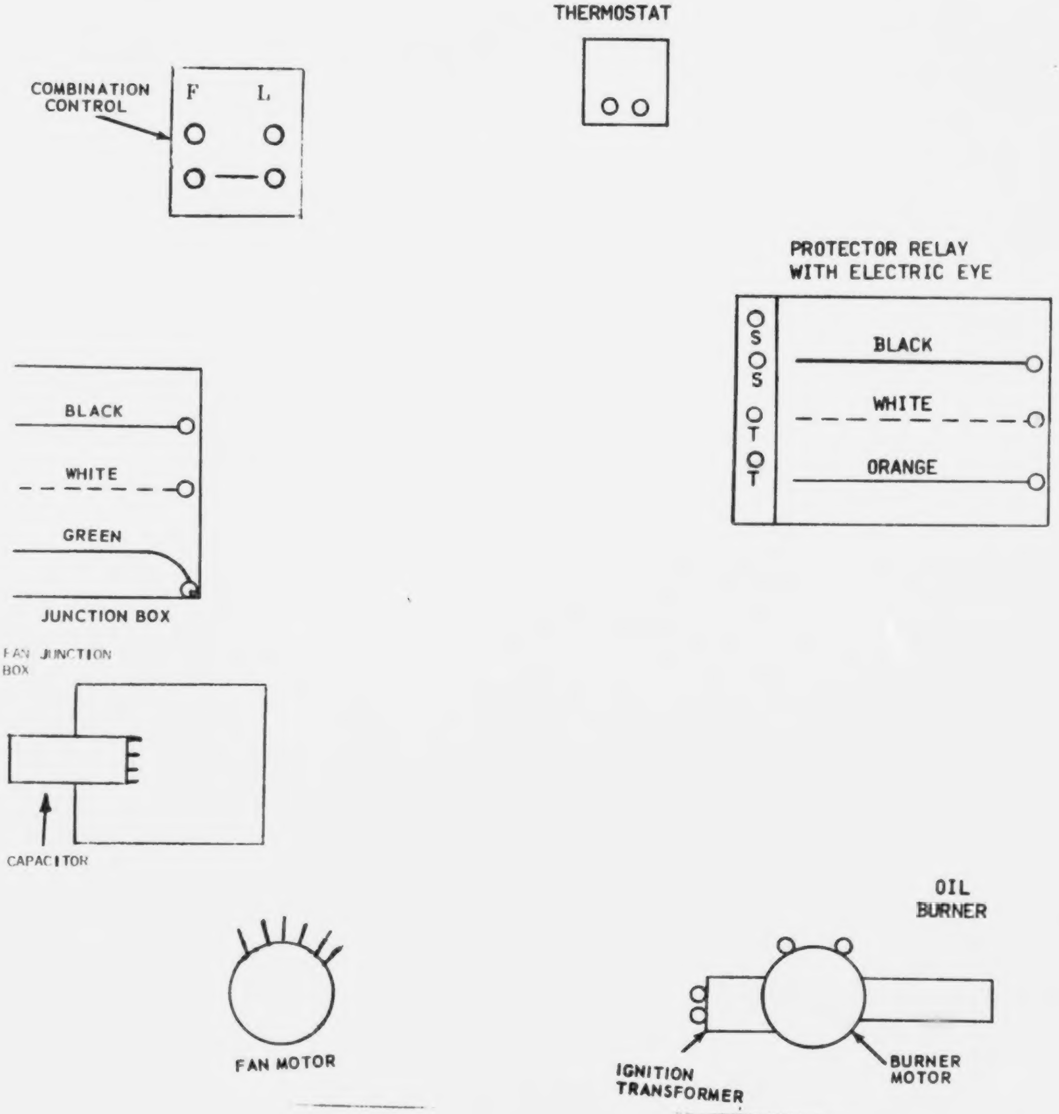

THERMOSTAT
COMBINATION CONTROL
F
L
PROTECTOR RELAY WITH ELECTRIC EYE
S
S
T
T
BLACK
WHITE
ORANGE
BLACK
WHITE
GREEN
JUNCTION BOX
FAN JUNCTION BOX
CAPACITOR
OIL BURNER
FAN MOTOR
IGNITION TRANSFORMER
BURNER MOTOR

Figure 7. Circuitry for an Oil-Fired Warm Air Furnace With Protector Relay Primary Control

# OIL FIELD SPACE HEATERS

## OBJECTIVE

This workbook was designed to guide you in identifying the procedures for removing, installing and maintaining oil fired space heaters.

## PROCEDURE

### EXERCISE 1

### Oil-Fired Space Heaters

Complete the following statements.

1. Name the types of oil fired space heaters.

2. List the three main parts of the natural draft pot type burner.

3. The maximum amount of oil that should be in the pot is ________________.

4. The only safety device on the oil fired space heater is the _____ ____ _____ _____.

5. What is the purpose of the manual control knob?

6. The most important part of the fuel oil control valve is the ______________. Why?

7. What starts and stops the flow of oil to the fuel oil control valve?

8. If flame failure occurs, what must be done before restarting the burner?

9. What causes draft in a chimney?

10. What device helps to maintain a constant draft?

# DOMESTIC AND INDUSTRIAL OIL BURNERS

## OBJECTIVE

Upon completion of this lesson, you will be able to:

1. Explain characteristics of oil, theory of gravity and forced fuel oil sypply system.
2. Install, operate and maintain rotary pumps.
3. Inspect and maintain fuel oil piping systems.
4. Perform preoperational checks and operate, adjust, maintain, troubleshoot and replace oil furnaces.

## INTRODUCTION

The Air Force uses many different types of oil burners. In this study guide we will cover the different types of fuel burning equipment. It will be done in two sections.

SECTION I -- Fuels and Fuel Systems

SECTION II -- Domestic and Industrial Oil Burners

## SECTION I

## FUELS AND FUEL SYSTEMS

## OBJECTIVE

To help you in learning the types of oil used in heating installations, including handling, piping systems and the pumps used to move this oil.

## INTRODUCTION

Many trees, ferns and other types of vegetation have grown, died, decayed and been covered with layers of the solid particles that form the earth's surface. Geologists believe that the decomposition of these minute marine growths or possibly of vegetable matter in some cases formed the oil which lies trapped in pools between layers of the earth's crust. This crude oil consists of complicated combinations of carbon and hydrogen called hydrocarbons.

## INFORMATION

### Characteristics of Oil

Fuel oils are derived from crude petroleum. This crude petroleum is a mixture of hydrocarbons and small amounts of nitrogen, sulfur, and vanadium; the amount of each substance present varies with petroleum source. The various products derived from petroleum, including fuel oils, are separated by fractional distillation. This is a process by which liquids with different boiling points are separated from solution by repeatedly evaporating and condensing portions of the mixture. See figure 4-1. In general, fuel oils can be divided into two major classifications; distillate and residual.

Distillate Fuel Oils. When the fractional distillation process is applied to crude petroleum, the gaseous and light substances boil off first, followed by the gasoline, the kerosene, and then the light and heavy distillate fuel oils ("gas oils").

**Residual Fuel Oils.** When marketed as a fuel, the "bottom" or residual material from the distillation process is called residual fuel oil. Since crude petroleums from various sources differ widely in composition, there is considerable difference in these oils. In general, they are heavy, dark and not as fluid as the lighter distillate oils.

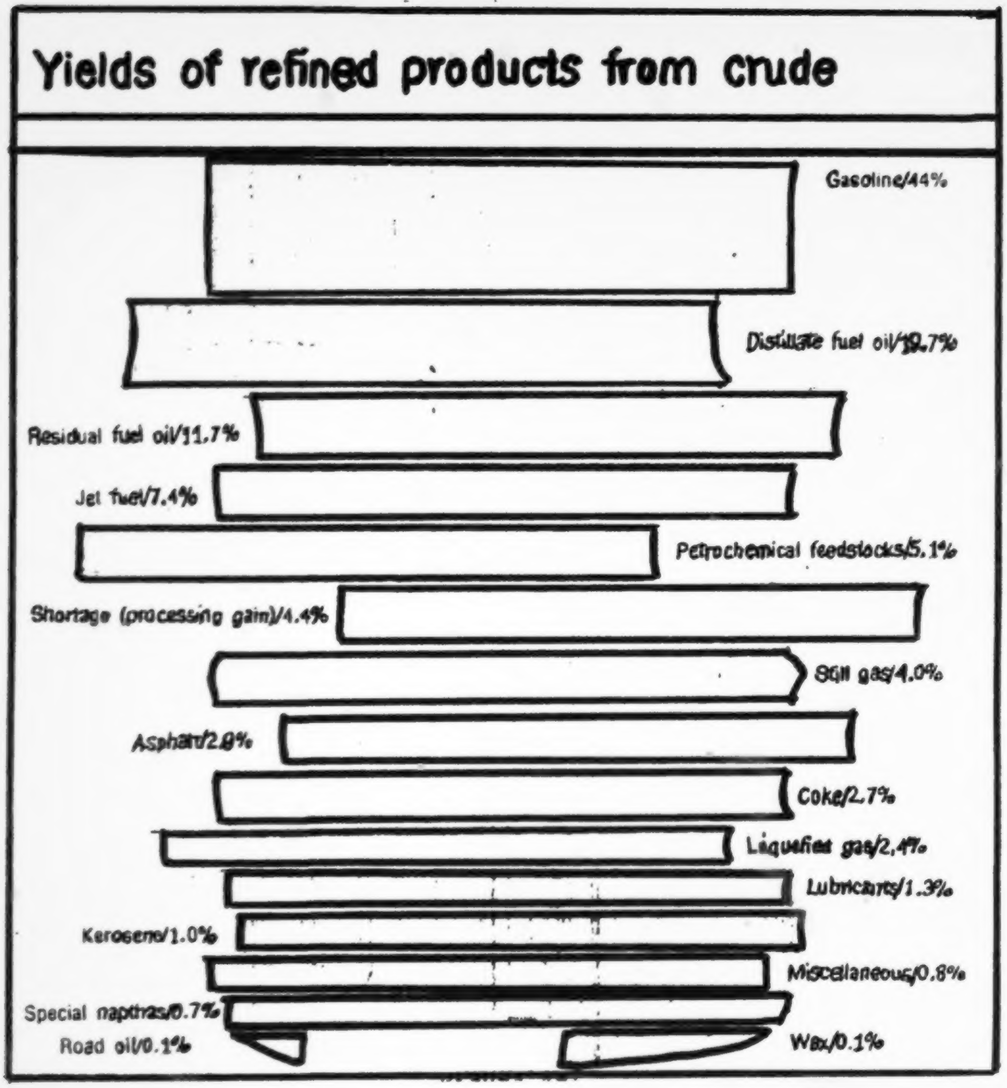


Figure 4-1

**Commercial Grade Fuel Oils.** Commercial-grade fuel oils are generally classified according to physical characteristics and use. These oils are intended for use in various types of fuel-burning equipment under various climatic and operating conditions, for the generation of heat in furnaces for heating buildings, for the generation of steam, or for other purposes. The grades covered by this specification are intended for specific applications as indicated below:

STUDY GUIDES

J3ABR54532 001-IV-1 thru IV-5

Technical Training

# Heating Systems Specialist

# SOLID, GAS FUEL BURNERS AND WARM AIR DISTRIBUTION SYSTEMS

April 1983

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## EXPLANATION OF TERMS

ABSOLUTE ZERO--Where molecular activity ceases (459.69°F).

ABSORPTION--Process of absorbing, to take in, make a part of.

ACCESSORIES--Items not essential, but adding to the convenience or effectiveness of something else.

ACCUMULATE--Collect, to increase in quantity.

ADJUSTMENT--To regulate, to bring to a more satisfactory state.

AGITATOR--Device for shaking or stirring.

ALIGNMENT--Putting into precise position, proper positioning or state of adjustment of parts.

ALTITUDE--The vertical elevation of an object above sea level.

ANALYSIS--Identification or separation of ingredients of a substance, separation of a whole into its component parts.

ANALYZER--Device used in analysis.

ANEMOMETER--Instrument for measuring and indicating the force or speed of the wind.

ANTHRACITE--A hard shiny coal.

AQUASTAT--A controlling device actuated by water temperature.

ASBESTOS--A fire-resistant material.

ASPHYXIATION--Death because of lack of oxygen.

ASPIRATOR--Device used to create a suction.

ATMOSPHERIC--Of or relating to the atmosphere.

ATOMIZATION --Act of atomizing, breaking into fine particles.

AUTOMATIC--Self acting.

AUXILIARY--Providing help, functioning in a subsidiary capacity.

BAFFLE--Use to direct flow of gases, steam or water.

BEARING--A machine part in which a shaft or pin turns.

BIMETALLIC--Composed of two different metals.

BINARY--Something constituted of two things or parts.

BITUMINOUS--Soft coal.

BLOWDOWN--Discharge, drain partially.

BONDING--Adhesive or cementing material.

BTU--British thermal unit, unit of heat measurement.

BURNER--Part of heating unit which produces flame.

CAKING--To form or harden into a mass.

CALIBRATION--To determine, a mark of graduation, the act or process of calibrating.

CAPACITY--Measure of content, maximum output.

CARBON--An essential part of coal and oil.

CARBON DIOXIDE--A gas consisting of one part carbon and two parts oxygen ($CO_2$).

CARBON MONOXIDE--A gas consisting of one part carbon and one part oxygen (CO).

CATHODIC PROTECTION--Reduction or prevention of corrosion of a metal surface using an electrical current flow.

CELSIUS--Thermometric scale, the interval between freezing and boiling is divided into 100 degrees.

CENTIMETER--Metric measurement equaling 0.39 inch; 0.01 of a meter.

CENTRIFUGAL--Going or acting in a direction away from a center or axis.

CHARACTERISTIC--Traits, qualities or properties.

CHIMNEY--Vertical structure enclosing a flue that carries off combustion gases.

CIRCUIT--The complete path of an electrical current usually including the source of electric energy.

CIRCULATE--To move, usually in a circle, circuit or orbit.

CLASSIFICATION--Division of a larger category.

CLASSIFIED--Divided into classes.

COEFFICIENT--A number that serves as a measure of some property or characteristic.

COMBINATION--Two or more, together.

COMBUSTION--Burning.

COMPENSATING--Making up for something.

COMPONENT--A part of.

COMPOSITION--Made up of.

CONCENTRATION--Act of steam turning back into water.

CONDUCTION--The act of conveying heat through an object.

CONDUCTIVITY--Ability to conduct.

CONSTANT--Always or lasting.

CONSUMER--A unit which uses steam or hot water.

CONSUMPTION--The usage of steam or hot water.

CONTROL--Having power over.

CONVECTION--The act or process of conveying.

COOLING--Reducing the temperature.

CORROSION--Act of eating away by degrees.

COUNTERWEIGHT--An equivalent poundage.

CSG--Commercial Standard Grade (grades of oil).

CYCLE--A sequence of a recurring succession of events.

DAMPER--A plate used to regulate the flow of air or gases.

DE-ENERGIZE--Remove the energy from.

DEMARCATION--The set limits of.

DENSE--Having high opacity, crowding together of parts, thick.

DESIGN--Plan or purpose.

DETERIORATION--The loss of strength, form or usefulness; to grow worse in quality.

DIAMETER--A straight line through the center of a circle.

DIAPHRAGM--Thin membrane divider or partition.

DIFFERENTIAL--The difference between two points.

DIFFUSERS--Device used to regulate velocity.

DIFFUSING--The act of regulating the velocity of.

DILUTES--Reducing the strength of.

DISASSEMBLING--Taking apart.

DISSIPATE--To cause to spread out or spread thin to the point of vanishing.

DISTILLATE--Light grade oils produced by distillation.

DISTINCTIVE--Having or giving style.

DISTRIBUTION--Giving out or supplying portions of.

DOMESTIC--Relating to the home or family.

DOWNDRAFT--Supply of air received down through a chimney.

EFFICIENCY--Measurement of operation or ability.

ENERGIZE--Give energy to.

EQUALIZE--To make equal.

EQUILIBRIUM--Balance.

EQUIPMENT--Implements used in an operation or activity.

ESSENTIAL--Necessary.

EXCESSIVE--Going beyond a limit.

EXCHANGER--Device used to change heating mediums.

EXHAUST--Already used once, to discharge, to draw off.

EXPANSION--Increase in size or volume.

EXTINGUISHED--Put out or killed.

FAHRENHEIT--A thermometric scale on which the boiling point is 212° and freezing is 32°.

FERRULE--Ring or metal put around a slender tube or shaft to strengthen it or prevent it from splitting.

FIXED CARBON--Nonvolatile carbon in coal and oil.

FLARED--A spreading outward.

FLEXIBLE--Bendable or pliable.

FLUCTUATION--Changing from a norm.

FLUE--An enclosed passageway for conveying combustion gases to the outer air.

FLUE GAS--Combustion gas.

FURNACE--Where initial combustion and burning of fuel takes place.

GAUGE--Instrument with a graduated scale for measuring or indicating quantity.

GRAVITY--Force that draws objects toward the center of the earth.

GROUNDING--The act of or an object that makes an electrical connection with the earth.

HEADER--Pipe or tube shared by two or more objects or devices.

HEATING--Increasing the temperature.

HOPPER--Usually funnel-shaped receptable for delivering coal.

HORIZONTAL--Parallel to the horizon.

HUMIDIFIER--Device used to increase the humidity.

HUMIDISTAT--Device used to sense humidity.

HUMIDITY--Moisture in the air.

IGNITION--Act of setting on fire.

IMPURITIES--Something not pure or makes something else not pure.

INDUSTRIAL--Relating to industry.

INERT--Having no inherent power of action, motion or resistance.

INFILTRATION--To pass into or through by filtering or permeating.

INOPERATIVE--Not functioning.

INSERTION--Act or process of inserting.

INSULATE--Protect or cover.

INTENSITY--The magnitude of force or energy.

INTERMITTENT--Coming and going at intervals.

LATENT HEAT--Heat that cannot be measured with or by a thermometer.

LIBERATES--Sets free.

LIGNITE--A brownish black, woody structured coal.

LPG--Liquefied petroleum gases.

LONGITUDINAL--Placed or running lengthwise.

LOUVER--An opening provided with slanted fixed or movable fins to allow flow of air.

LUBRICATE--To make slippery, usually with grease or oil.

MANIFOLD--Header.

MANUAL--Operates by hand.

MANUFACTURED--Artifically produced.

MECHANICAL--Operated by a machine.

MECHANISM--Mechanical operation or action.

MEDIUM-- A means of effecting or conveying something.

MOISTURE--Wetness.

NATURAL--Made by nature.

NON-RECESSED--Not set into.

NOZZLE--A projecting spout, terminal discharging pipe.

OBSTRUCTION--Blockage.

OPERATING--Causing a function to take place.

ORIFICE--Hole or opening.

OXYGEN--A gas without color, taste or odor, and is a chemical element (O).

PARTICLE--One of the minute subdivisions of matter.

PASSAGE--Channel, course, tunnel or corridor.

PERIMETER--The boundary of a closed plane figure.

PERIODIC--Fixed interval between set times.

PERTINENT--Relevant or applicable.

PILOTSTAT--Control on the fuel line of a pilot.

PIPETTES--A narrow glass tube into which the liquid is drawn by suction.

PLENUM--An enclosed space in which the air pressure is greater than the outside atmosphere.

POLLUTION--Impure or unclean.

PORCELAIN--Ceramic that is hard, translucent and white.

PRECIPITATOR--Device used to cause to separate or condense.

PREDETERMINED--Decided or chosen beforehand.

PRELIMINARY--Something that precedes.

PRESSURE/PRESSURIZING--Force exerted over a surface divided by its area.

PROPELLER--A device that drives or forces forward or onward.

PROPORTIONAL--Having the same or constant ratio.

PULVERIZED--Reduced to very small particles.

PURGE--Clean out.

QUANTITY--Amount (how many).

RADIANT--Emitted or transmitted by radiation.

RADIATION--Energy radiated in waves or particles.

RADIATOR--Nest of pipes or tubes used to heat by radiation.

REASSEMBLE--Put back together.

RECIRCULATE, RECIRCULATING--Moving something back through system.

RECTANGULAR--Having or resembling the shape of a rectangle.

REFERENCE--Consultation of sources or information.

REFRACTORY--Heat resisting nonmetallic ceramic material.

REGULATE--To control something.

REGULATOR--Device which regulates.

RESPONSE--Reply or reaction.

RESTRICT--To limit.

RETURN--To bring, send or come back to the starting point or place.

ROTATION--The turning of a body on an axis.

SATURATION--Moisturizing to the maximum limit.

SEMIBITUMINOUS--A type of coal.

SENSIBLE HEAT--Heat that can be felt or sensed.

SHUTOFF--Something that stops the flow of gas, water or oil.

SLAGGING--The flowing together of coal impurities.

SMOKE PIPE--The vent pipe used to remove smoke and gases from the firebox of a furnace or boiler.

SOLENOID--An electromagnetic valve or switch.

SPONTANEOUS--Without external stimulus.

STABILIZER--Substance that prevents chemical change.

STATIC ELECTRICITY--Electricity produced by atmospheric conditions or various natural or man-made electrical disturbances.

STATIONARY--Fixed, not moving.

STOKER--A machine for feeding a fire.

STRAINER--Device used to remove impurities from water and steam lines.

STRATIFICATION--Act or process of stratifying.

SUPPLY--To provide for.

SYNTHETIC INTOXICATION--Artificial intoxication.

SYSTEM--An assemblage or combination of things or parts forming a complex or unitary whole.

TEMPERATURE--A measurement of heat in degrees Fahrenheit or Celsius.

TENSION--Condition or degree of being stretched to stiffness.

THERMOCOUPLE--Thermoelectric couple used to measure temperature differences.

THERMOPILE--Multi-thermoelectric couples.

THERMOSTATIC--Controlled by temperature.

THROTTLED--Decreasing the flow.

TRANSFER--Move something from one place to another.

TROUBLESHOOTING--Looking, in a logical sequence, for a problem.

TURBULENT--Causing unrest, violence or disturbance.

VAPORIZATION--Act, process or state of being vaporized.

VAPORIZING--To convert, by heating or spraying, into a fine mist or vapor.

VELOCITY--Quickness of motion.

VELOMETER--Device used to measure velocity.

VENTILATION--Circulation of air.

VENTURI--Funneled tube used to measure flow.

VISCOSIMETER--Device used to measure viscosity.

VOLUME--Space occupied, measured in cubic units.

VOLUMETRIC--Relating to the measurement of volume.

# GAS BURNERS

## OBJECTIVE

This study guide was designed to aid you in operating and maintaining gas burners.

## INTRODUCTION

Natural gas is an ideal fuel because it burns easily, requires comparatively simple equipment, and is clean. It is a comparatively dangerous fuel because it mixes easily with air and burns readily. Extreme care must be exercised to prevent or stop any leakage of the gas into an unlit furnace or into the boiler room.

Gas pressures vary widely and are usually transmitted at a pressure too high to be used in a heating unit without reduction. These high pressures are generally reduced to a pressure varying from two ounces to approximately 30 pounds per square inch (psi) depending upon the type and size of the burner used.

The reduction in pressure is accomplished by a pressure regulator valve, which when once adjusted, will maintain a fixed pressure to the burner as long as the main line pressure remains above the set pressure of the regulating valve.

After the gas is reduced to the proper pressure at the regulating valve, it is forced out of an orifice or tip called a spud. The gas draws air along with it and is discharged into a burner where the gas and air are mixed and burned. Air may be supplied to the burner at atmospheric pressure, or the burner may be encased in a duct and air supplied to it under pressure by a blower.

Unlike oil, gas is ready for combustion when it is delivered to the burner; thus, the function of the gas burner is that of proportioning and mixing the gas and air.

This study guide will provide you specific information concerning gas burners under the following main topics:

-- Characteristics of Gas

-- Gas Piping Systems

-- Types of Regulators

-- Theory of Construction of Gas Burners

-- Gas Burner Systems Maintenance

-- Safety Procedures for Operating Gas Burners

## INFORMATION

### Characteristics of Gas

#### Gas

Gaseous fuels are usually classified by the source from which they originate, which in turn determines their chemical composition. The heat value varies with the type of gas being used and will determine the quantity required for the specific capacity of the heating system. In the United States there are several types of gas. The ones principally in use are natural gas, liquified petroleum gases (LPG), manufactured or by-product gases, and biomass.

NATURAL GAS. Natural gas is by far the most important gaseous fuel for commercial applications. Its high heating value gives it a considerable economic advantage over relatively expensive manufactured gases. Natural gas is produced in more than 30 states and widespread pipeline networks make it available in some parts of nearly every state.

From the standpoint of trouble-free performance and ease of handling and control, natural gas offers many advantages that make it the most desirable of all heating fuels. It is generally available in a wide range of pressures to meet the requirements of both large and small installations.

Natural gas is colorless and odorless in its natural form; however, a distinctive odor is added to this gas as a safety factor to warn of leaks. Natural gas is lighter than air and upon escaping rises and mixes with air.

Composition of natural gas varies with the source, but methane ($CH_4$) is always the major constituent. Most natural gases contain some ethane ($C_2H_6$) and a small amount of nitrogen. Natural gas, like all gaseous fuels, mixes readily and intimately with air to form a clean burning combustible mixture. Since natural gas is substantially free of ash, combustion is practically smokeless and there are no boiler slagging or air contamination problems.

LIQUEFIED PETROLEUM GASES (LPG). The principle liquefied petroleum gases are propane and butane. They are closely related and are all derived from natural gas or petroleum refining gas. These gases are on the borderline between a liquid and a gaseous state.

In its natural state liquefied petroleum gas is odorless, colorless and tasteless. It is odorized with the same odorant used for natural gas. Neither natural nor odorized LPG is poisonous. However, exposure to a room or pitfull of gas causes a synthetic intoxication and finally asphyxiation (smothering) results.

Maintenance for liquefied petroleum fuel systems is practically the same as for natural gas fuel systems. Liquefied petroleum gas is heavier than natural gas and, therefore, quickly settles to low places. For this reason, all valves and connections should be tight to prevent gas leaks. Soap solution should be used to check for gas leaks. Never use a flame of any kind.

Since these gas vapors settle, considerable safety hazards exist in event of leakage. It takes only two to nine percent of gas in the air to form a combustible mixture. A larger or smaller percentage of fas in air makes the fuel unburnable. In the liquid state or as pure vapor, the gas is not combustible or explosive.

PROPANE. Propane is generally available by bottle or cylinder or in bulk form. Propane is usually the most common of the liquefied petroleum gases.

BUTANE. Butane is generally not available in bottles or cylinders but more common in bulk form. It is quite common to have propane mixed with butane to obtain a desirable heat value and boiling point.

CHARACTERISTICS OF LPG. The boiling or vapor point at atmospheric pressure with necessary heat of vaporization added, butane will boil or change from a liquid to a gaseous state at 32°F. In other words, if its temperature is 32°F or lower and the pressure is atmospheric, butane will remain a liquid. To convert this liquid to a gaseous form, the boiling or vaporization point must be obtained. The boiling point of propane is -42°F. If there are anticipated freezing temperatures, propane will cause less handling difficulties.

Liquefied petroleum gases are compressed into suitable containers to a pressure up to 200 pounds per square inch, at the refinery. At these pressures, the gas is changed to a liquid. When the gas is used, the prssure must be reduced to approximately 6 to 8 pounds per square inch. This reduction in pressure causes the liquid to change to a gas. Liquefied petroleum gases are readily combustible and produce an intense heat.

MANUFACTURED OR BY-PRODUCT GASES. This group consists of those gases that are manufactured by converting low grade liquid and solid fuels (oil, coal, wood or waste material) into gaseous form or they are a by-product from furnace or processing operations. The most common manufactured gases are carbureted water gas, oil gas and producer gas. They are ordinarily used at or near the production point since high manufacturing cost rules out the added expense of distribution.

The most common by-product gases are blast furnace gas, casinghead gas, refinery gas and sewage gas. This group of gases is usually used at the source of production (oil fields, refineries, disposal plants). It is produced in varying quantities, must be used as fast as it is produced, and can be piped only comparatively short distances. For this reason, its use for heating is limited to those installations near the producing plant. This gas carries a large amount of dust and, therefore, must be partially cleaned. Usually heating units which burn blast furnace gas are designated with oversized combustion chambers since large quantities of gas must be burned to obtain a minimum amount of heat due to low heating value of the gas.

BIOMASS. Biomass is generally defined as organic matter capable of providing heat. It can be either burned directly or chemically converted to a burnable fuel. Standing vegetation, seaweed, lumbering wastes and wood chips, agricultural wastes, and combustible municipal wastes (excluding sewage) are all considered biomass.

Conversion of biomass from either farms or trash and garbage to liquid or gaseous fuels is technically feasible, but most applications are not yet economically favorable. Problems relating to collection, transportation, seasons, guaranteed availability, and environmental impacts must be overcome before this kind of use can be expanded.

Because biomass is expensive to collect and transport, the most likely users will be rural industries and utilities located near available resources, along with the biomass producers themselves. Utility interest in bioconversion has increased considerably. The number of bioconversion projects increased 48 percent between 1979 and 1980 as several utilities began assessment studies or large-scale demonstration projects.

## Gas Piping Systems

These are systems that deliver gas from a source of supply through a large distribution system to the services that are using this gas. Below is a description of each.

Feeder Mains. These lines deliver the gas from the source of supply to the district regulator. The pressure necessary to operate these lines vary from 50lbs to thousands of pounds. They are used to transport the gas only.

Distribution Mains. Distribution lines distribute gas from the district regulator throughout the installation. The amount of gas pressure used in these lines is only enough to overcome the friction and turbulence loss. The pressure range for a distribution system is from 1 1/2 to 50 psi.

Service Lines. A gas service line extends from the distribution line to the point of consumption (building, house, etc.). Since the service line is attached to the distribution line then the amount of gas pressure in the service line is the same as the distribution line. Therefore, it is necessary to install a device on the line to reduce the pressure to the amount necessary for the system it is servicing. This device is called a gas pressure regulator.

In order for a gas supply system to operate properly two types of piping systems have been designed. They are called Loop and Radial. The design of both these systems determine the amount of pressure necessary for the proper operation.

Loop. The loop system is the better of the two because it "loops" around the city, base, etc. By looping the system you can isolate a section at a time and still not effect the operation of the rest of the system.

Radial. In a radial piping system one line supplies gas to numerous buildings off the main line. This type of system generally needs to operate at a higher pressure than the loop system because of the long dead ends. Also, in order to isolate a section might require shutting off the gas to half the system.

### Gas Lines

When locating new gas lines, safety should be the main item in construction. Lines should not be located in unventilated spaces, such as under floors, concealed in walls, extending through attics, etc. A gas leak in a confined area not ventilated may cause an explosion. Whether gas lines are located above or below ground, they should not be exposed to freezing weather.

Due to the low pressures used in gas systems, steel pipe and fittings of malleable iron or forged steel may be used.

Gas pipes should be securely fastened and supported with hooks, straps, bands or hangers at intervals of not more than eight to ten feet, depending upon the pipe size.

Gas lines from the main supply to the burner should be graded at least one inch for every 50 feet of pipe. The main gas valves should be installed outside of the building so that it could be easily accessible in case of a fire within the building. The trend in present day building construction places both the main gas valves and gas meters near the outside of the new construction.

The master shutoff gas valve is usually located in the gas supply line at the point where the line enters the building or installation. It is used to shut off the gas to the heating unit or units. The pressure regulator is usually installed next to the gas shutoff valve. It is used as a station to reduce the high gas pressure in the line. In some cases, the gas pressure may be reduced through several stations, each station reducing the pressure slightly. This is done so that if one station fails, the rest of the stations would have some control over the flow or pressure. The gas meter is usually installed in the line next to the pressure regulator. Its purpose is to record the amount of gas used.

Liquefied Petroleum Gas. Liquefied petroleum gases are readily combustible and produce an intense heat. In their pure state, they are odorless; however, an odorant is added to insure detection in case of a leak in the tank or piping.

Liquefied petroleum gas supply systems are similar to natural gas supply systems. However, the liquefied petroleum gas is obtained from a tank located near the heating unit while natural gas is piped from gas fields.

Installation procedures for the supply line from the tank to the heating unit are similar to those for natural gas. In most cases, the pressure regulator and main valve are located in the line near the tank. No gas meter is utilized in this system. However, a gas gauge located on the tank serves to indicate the amount of gas in the tank.

Maintenance for liquefied petroleum fuel systems is practically the same as for natural gas fuel systems. Liquefied petroleum gas is heavier than natural gas and, therefore, quickly settles to low places. For this reason, all valves and connections should be tight to prevent gas leaks.

Leak Detection. Gas pipes should never be used as part of an electrical ground system -- cold water pipes are preferred.

When placing a new installation into service, a leak test should be made at each connection with the system under pressure. A solution of soapy water should be applied by brush at each joint to check for gas leaks. If a gas leak exists, a soap bubble will form at the leak.

CAUTION: Never use a lighted match or candle to check for gas leaks, since the escaping gas is apt to ignite causing an explosion and possibly a fire.

## Components and Controls

### Control Systems

Gas-fired burners may be equipped with any number or combination of manual as well as automatic control devices.

The simplest control system available for a burner is one which is equipped with only a manual gas shutoff valve. A burner, with a system of this type, must be ignited when the gas shutoff valve is turned on. The use of this system is hazardous, because of escaping gas in case the burner is accidentally extinguished.

Some burner control systems may be equipped with the same manual gas shutoff valve as the former system, but with an added feature of a pilot light. A system of this type is much more convenient than the system with only the gas shutoff valve, because the pilot light which burns continuously is used to light the main burner when the gas shutoff valve is turned on. However, this system is just as hazardous as the system that does not use the pilot light.

Other burner systems employ the use of the pilot light, thermocouple and some type of automatic gas valve to control the burner. In this system, when the pilot light is extinguished, the automatic gas valve shuts off the gas flow to the main burner, but not to the pilot light. However, the gas valve will not open until the pilot light is ignited again. The escaping gas from the pilot light is assumed to be negligible and will be carried away by the flue of the heating system (natural gas only).

Still other gas burner systems use a combination control arrangement composed of a pilot light, pilotstat, thermocouple and some type of an automatic gas valve, as illustrated in figure 1-1. This system functions in a similar manner to the system that does not use the pilotstat mentioned in the previous paragraph. The valve type pilotstat is another added safety feature. Its purpose is to shut off the supply of gas to the pilot light as well as the main burner if the pilot light is extinguished. To relight the pilot, the reset button on the pilotstat must be reset.

The burner control systems mentioned are by no means the only types used; there are many more, but space in this publication does not permit a discussion of each individual type.

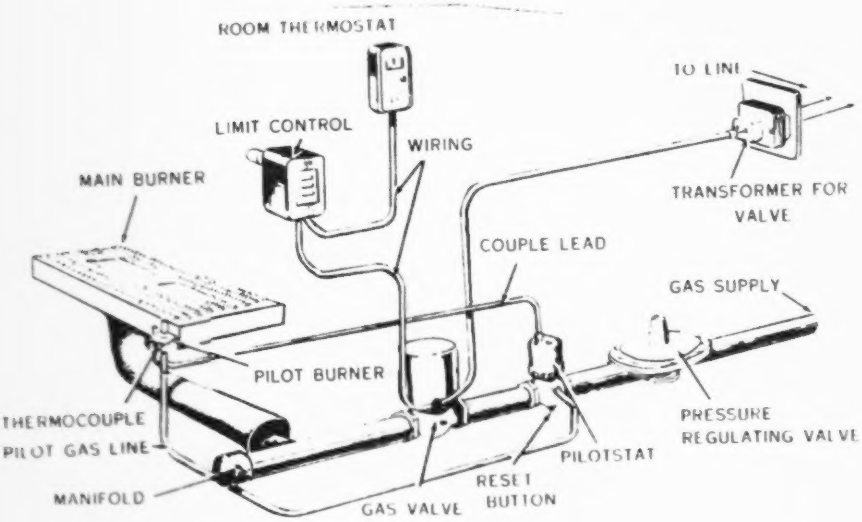

ROOM THERMOSTAT
TO LINE
LIMIT CONTROL
WIRING
MAIN BURNER
TRANSFORMER FOR VALVE
COUPLE LEAD
GAS SUPPLY
PILOT BURNER
THERMOCOUPLE
PRESSURE REGULATING VALVE
PILOT GAS LINE
PILOTSTAT
RESET BUTTON
MANIFOLD
GAS VALVE

Figure 1-1. An Automatic Gas Burner Control System

## Manual Gas Valve

A manual gas valve on a heating unit is usually installed next to the gas pressure regulator. It is used to shut off the gas to the heating unit in case some of the controls are being repaired or replaced.

## Pressure Regulators

Gas Pressure Regulators are devices installed in the gas line to reduce the pressure of the gas to that which is necessary for the system consuming the gas. Regulators are classified by the method of loading.

**Weight Loaded Regulator.** See Figure 1-2. The operation of a weight-loaded regulator is fairly simple. As gas enters the bottom chamber under the diaphragm pressure builds up causing the valve to close off. As the pressure on the outlet side decreases the weight of the arm pushes the valve open allowing more gas to enter and the whole process starts over again. This will continue until the gas supply is shut off.

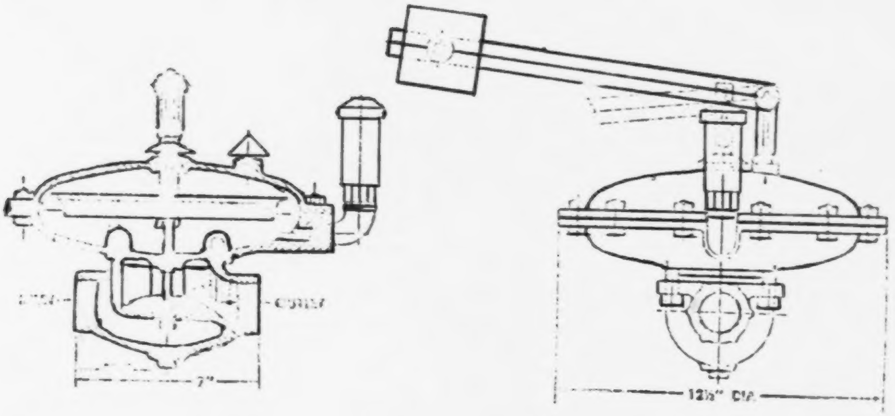


Figure 1-2. Weight-Loaded Regulator

**Spring-Loaded Regulators.** The operation of a spring-loaded regulator is the same as a weight-loaded except that it uses a spring to act as a counter force instead of a dead weight. This type of regulator is used generally as service or appliance regulators, where they maintain gas pressure to an individual building or appliance. Figure 1-3.

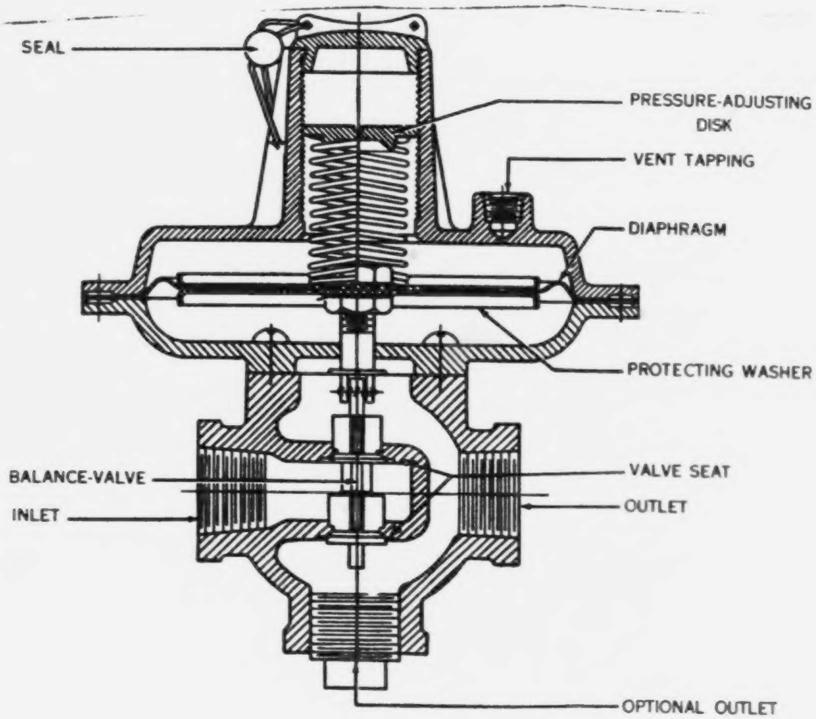

SEAL
PRESSURE-ADJUSTING DISK
VENT TAPPING
DIAPHRAGM
PROTECTING WASHER
BALANCE-VALVE
VALVE SEAT
INLET
OUTLET
OPTIONAL OUTLET

Figure 1-3. Spring-Loaded Regulator

Pressure-Loaded (Pilot-Operated) Regulators. The operation of these type of regulators is controlled by a pilot-regulator. This pilot regulator controls the power necessary to open or close the valve rather than weights or spring pressure. See Figure 1-4.

This type of regulator is held closed by spring pressure until enough gas pressure builds up on the opposite side of the diaphragm. This force must be greater than the spring tension. Therefore the counter-force must be controlled. This is done by the small regulator on top of the main regulator. It "senses" the pressure downstream and thereby controls the amount of pressure exerted on the top of the diaphragm. These regulators are used mainly on the distribution mains to reduce from high to medium pressure.

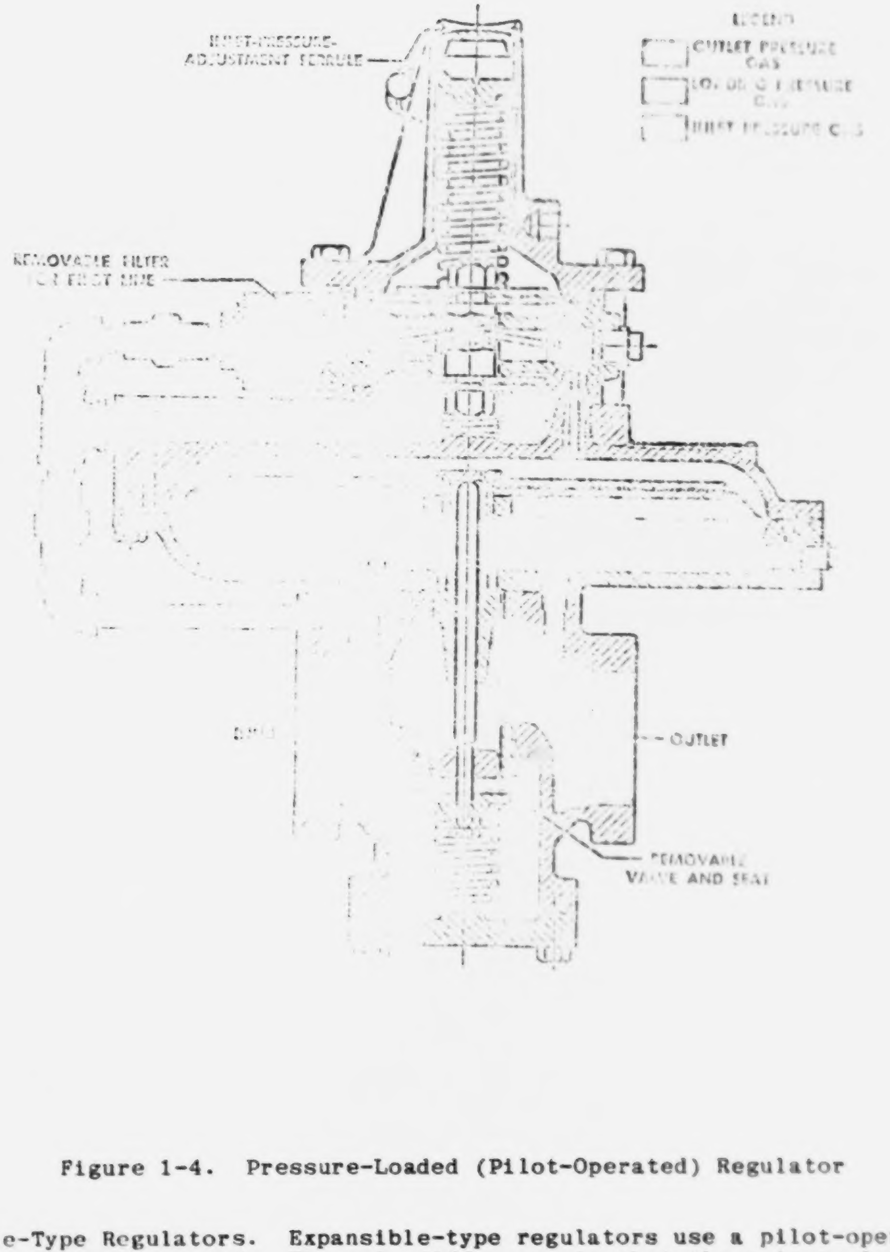

INLET-PRESSURE-ADJUSTMENT FERRULE
LEGEND
OUTLET PRESSURE GAS
LOADING PRESSURE GAS
INLET PRESSURE GAS
REMOVABLE FILTER FOR PILOT LINE
INLET
OUTLET
REMOVABLE VALVE AND SEAT

Figure 1-4. Pressure-Loaded (Pilot-Operated) Regulator

Expansible-Type Regulators. Expansible-type regulators use a pilot-operated regulator as previously stated. The main difference is that there is no longer a diaphragm or spring. This regulator uses an expansible tube. By controlling the pressure on the outside of the tube you control gas flow. These regulators are used mainly for the distribution mains to reduce from high to medium pressure. See Figures 1-5 a, b, c.

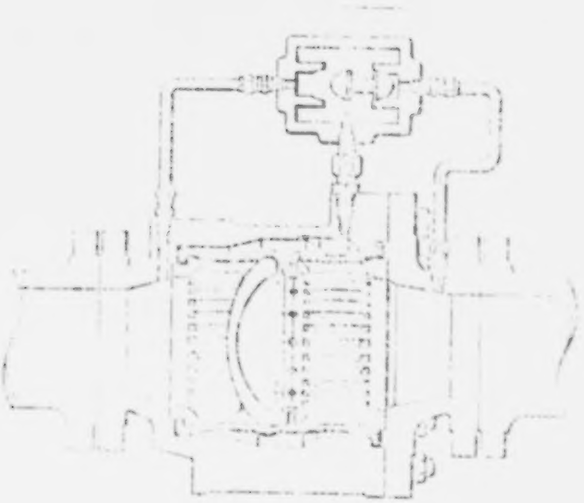


Figure 1-5a. Expansible Tube Regulator - Closed Position

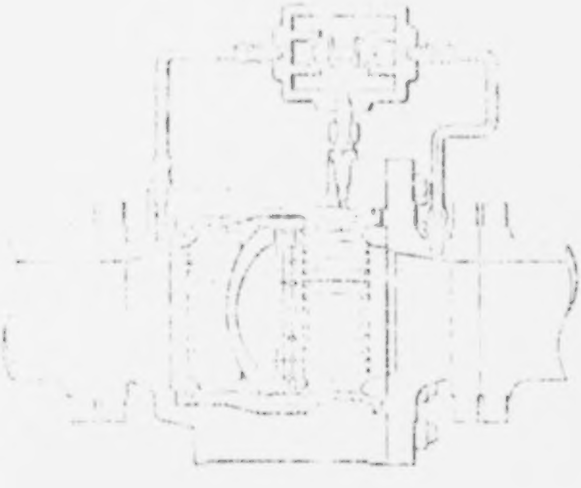


Figure 1-5b. Expansible Tube Regulator - Throttling Position

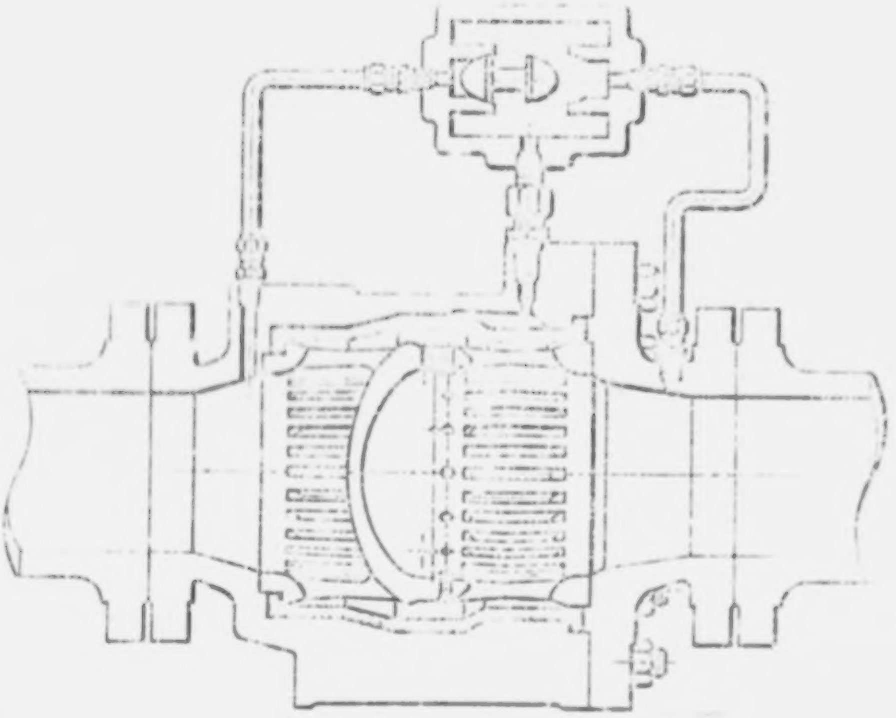


Figure 1-5c. Expansible Tube Regulator - Open Position

Pilotstat (Safety Pilot)

A pilotstat is a safety device used on certain heating units which shuts off the flow of gas to the main burner if the pilot light fails.

The thermoelectric pilotstat shown in figure 1-6 will break the circuit to the main gas control valve causing it to close and remain closed if the pilot flame is extinguished. This action is satisfactory for use on standard gas installations. This unit does not provide for 100 percent shutoff; therefore, it should never be used with LP gas.

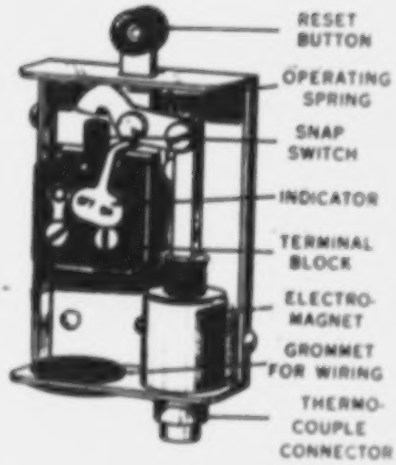

RESET BUTTON
OPERATING SPRING
SNAP SWITCH
INDICATOR
TERMINAL BLOCK
ELECTRO-MAGNET
GROMMET FOR WIRING
THERMO-COUPLE CONNECTOR

Figure 1-6. Thermoelectric Pilotstat

The valve type pilotstat shown in figure 1-7 will shut off the gas supply to the main burner and pilot (100 percent shut off) if the pilot flame is extinguished. This feature is required on LPG installations and is recommended for the other types of gas.

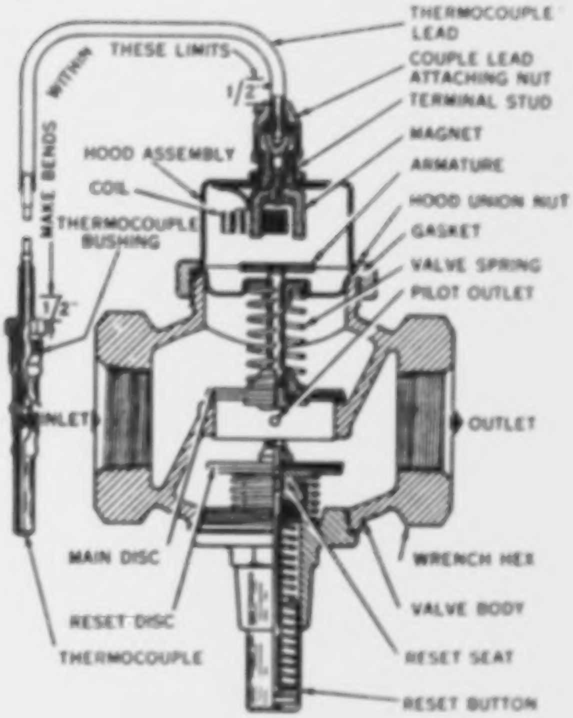

THERMOCOUPLE LEAD
WITHIN THESE LIMITS
1/2"
MAKE BENDS
COUPLE LEAD ATTACHING NUT
TERMINAL STUD
MAGNET
HOOD ASSEMBLY
ARMATURE
COIL
HOOD UNION NUT
THERMOCOUPLE BUSHING
GASKET
VALVE SPRING
1/2"
PILOT OUTLET
INLET
OUTLET
MAIN DISC
WRENCH HEX
VALVE BODY
RESET DISC
THERMOCOUPLE
RESET SEAT
RESET BUTTON

Figure 1-7. Valve Type Pilotstat

Automatic Gas Valve

The primary control for a domestic gas burner is an automatic valve that opens or closes in response to the thermostat signals. There are three common types of automatic gas valves. The three types are Solenoid, Diaphragm and the Motorized gas valves.

SOLENOID GAS VALVES. The basic principles used in all solenoid gas valves are similar. However, the design of each individual unit differs. The two most common types of solenoid gas valves are discussed in the following paragraphs.

Standard Solenoid Gas Valve. The solenoid gas valve shown in figure 1-8 is of the electric type. It is suitable for use with gas furnaces, steam and hot water boilers, conversion burners, and industrial furnaces. This valve operates under the action of either a thermostat, limit control, or other device that closes a circuit to energize a coil. The energized coil operates a plunger causing the valve to open. Whenever there is a current failure, the valve automatically closes, causing the gas pressure in the line to hold the valve disc upon its seat. In order to open this valve during current failure, it is necessary to use the manual opening device at the bottom of the valve. When electric power is resumed, place the manual opening device in its former position.

NOTE: When the valve is opened with this manual opening device, all safety devices are bypassed.

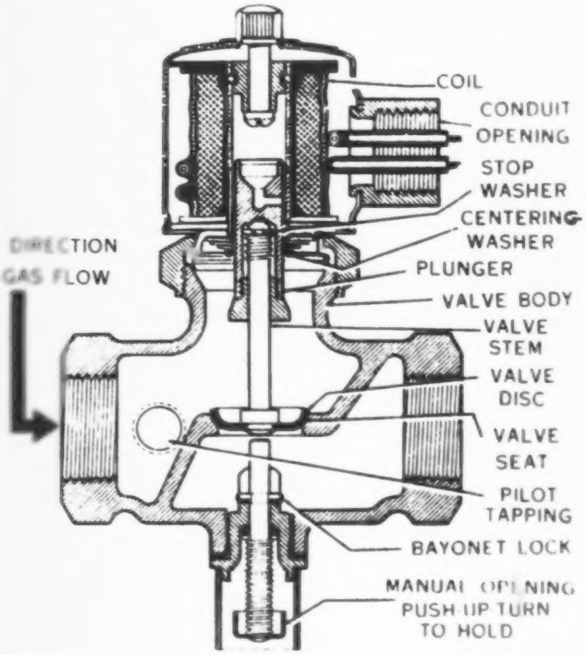

COIL
CONDUIT OPENING
STOP WASHER
CENTERING WASHER
DIRECTION GAS FLOW
PLUNGER
VALVE BODY
VALVE STEM
VALVE DISC
VALVE SEAT
PILOT TAPPING
BAYONET LOCK
MANUAL OPENING PUSH-UP TURN TO HOLD

Figure 1-8. A Solenoid Gas Valve

**Recycling Solenoid Gas Valve.** The solenoid gas valve illustrated in figure 1-9 may be used with the same kind of heating equipment as the standard solenoid gas valve. The design of this valve differs from the standard gas valve, in that it is equipped with an automatic recycling device, which allows the valve to be switched to manual operation during current failure. However, upon the resumption of electric current, this valve automatically returns to the control of the thermostat.

**DIAPHRAGM GAS VALVE.** The diaphragm gas valve, illustrated in figure 1-10 may be used interchangeably with the solenoid gas valve. Its main feature is the absence of valve noises when opening and closing. In this type of diaphragm valve, the polarized relay energizes and opens the three-way valve allowing the gas to flow out of the upper chamber of the unit. Reducing the pressure in the upper chamber in this manner causes the diaphragm to flex upward and open the gas valve. When the polarized relay is de-energized, the three-way pilot valve allows gas to flow into the upper chamber increasing the pressure, and thereby closing the gas valve.

**MOTORIZED GAS VALVE.** An electric motor is mounted on top of the motorized gas valve. When the motor is energized, it holds the valve open in what is known as the stalled position; when it is de-energized, a return spring closes the valve. The motorized valve has provision for manual operation when required.

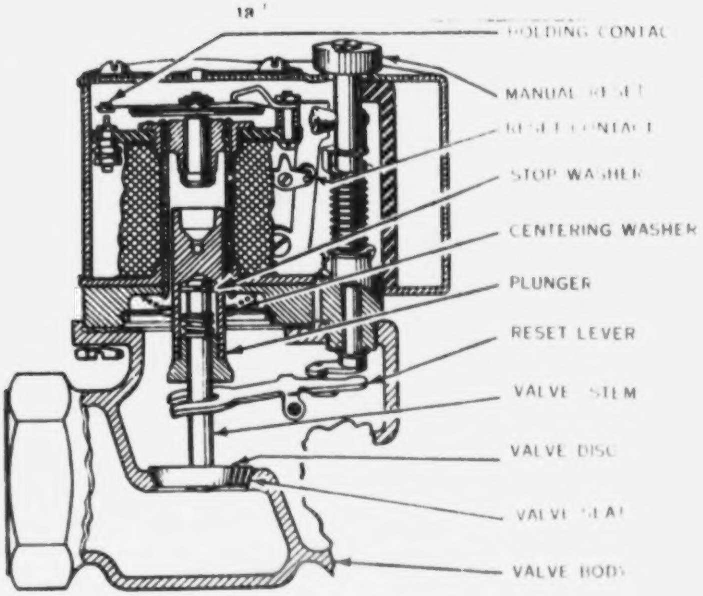

HOLDING CONTAC
MANUAL RESET
RESET CONTACT
STOP WASHER
CENTERING WASHER
PLUNGER
RESET LEVER
VALVE STEM
VALVE DISC
VALVE SEAT
VALVE BODY

Figure 1-9. Recycling Solenoid Gas Valve

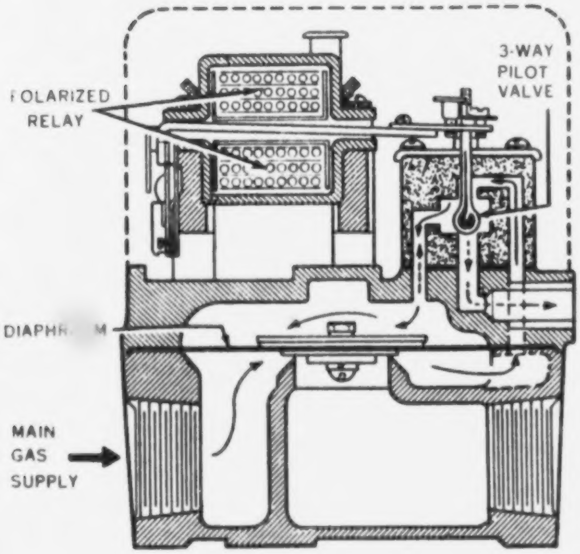

POLARIZED RELAY
3-WAY PILOT VALVE
DIAPHRAGM
MAIN GAS SUPPLY

Figure 1-10. A Diaphragm Gas Valve

### Combination Gas Valve

The combination gas control valve is referred to as a combination control because it contains a manual main and pilot valve, an automatic pilot device, in addition to the electrically-operated diaphragm type automatic gas valve and a pressure regulator. The pressure regulator is deleted when this control is used on LP gas.

### Manifold

The manifold is that part of the gas line which feeds gas to the spud or orifice. It is made of black iron pipe.

### Spud

The spud screws into the manifold and also houses the orifice.

### Orifice

The orifice screws into or onto the spud. It could also be screwed into the manifold and slid into the spud. The size of the orifice determines the amount of gas that will go to the burner. To change the burner output, you would have to change the orifice.

## Theory and Construction and Operation of Gas Burners

Gas burners may be classified according to the pressure of the gas supplied to the burner or by the manner in which the gas and air is mixed. As there is no fine line of distinction between these methods of classification, we will discuss both methods used for classifying gas burners.

Usually gas burning systems are classified according to the gas pressures each one uses. These are: high pressure and low pressure.

### Supply Pressure Method

The low-pressure systems are generally designed for relatively low capacities and operate with a natural gas pressure of approximately two ounces to three pounds.

The high-pressure systems operate with a gas pressure of approximately one to 30 pounds. These systems are usually equipped with an air blower which supplies air under pressure for combustion. The piping used for the high-pressure systems is usually the same as that used for the low-pressure systems. However, special emphasis is placed on tightness of the joints and pipe. Welding is often used to insure tightness.

### Mixing Location Method

PREMIXING BURNER. (Figure 1-11) Although gas burners are generally classified according to the pressure they use, they can also be classified according to how each mixes the gas and air together. In the premixing type burner, air (primary air) passes through the air shutter and meets with the gas in the mixing head. They are mixed together in the throat and complete their mixing as they flow through a tube called the mixing tube or venturi tube. The mixed gas and air then flows to the burner head. Additional air (secondary air) is required for complete combustion. Burners of this type vary from the common atmospheric burner used in gas appliances to the high-pressure gas burners used for industrial purposes. Another type of premixing burner is in figure 1-1.

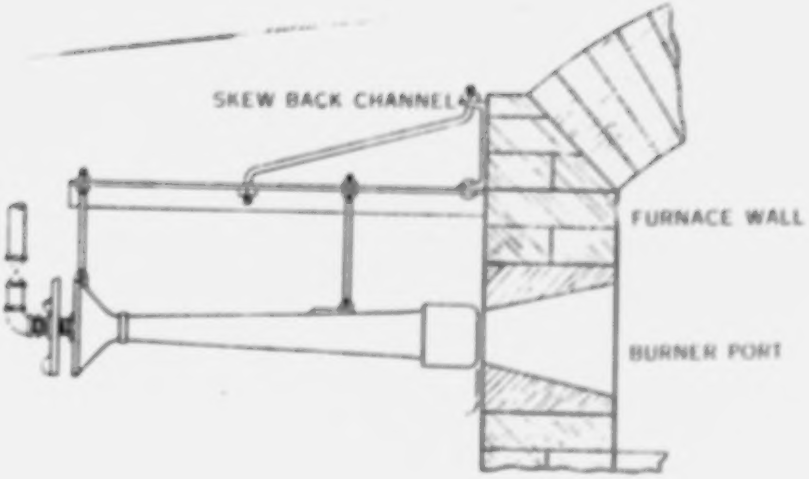


Figure 1-11. Premixing Burner

Ports

The ports are located on the burner head and are where the gas and air mixture comes out of the burner. There are four main types of burner ports: raised, slotted, drilled and ribbon.

Pilot Light

A gas pilot light in a gas heating unit is a small continuous burning flame that lights the main burner during normal operation of the heating unit. It is located near the main burner.

The gas flow to the pilot light in some cases is supplied by a small manually operated gas shutoff valve located on the main gas line above the main gas valve. In other cases, the gas may be supplied from the pilot tapping of a solenoid gas valve as shown in figure 1-8. In more expensive heating units, gas for the pilot light may be supplied by a pilotstat.

NOZZLE-MIXING TYPE. (Figure 1-12) In this type of burner, air and gas are separated and do not mix until they are released to the combustion chamber. In some burners, the velocity of the gas emerging from the individual burner jets is used to draw the primary air into the combustion area; others utilize draft fans to supply the incoming air (primary air) stream. An example of this style of design is the register type gas burner. This design is also widely used in the combination gas and oil burner.

Combination gas and oil burners are used for the purpose of firing two different fuels. This does not mean that both types of fuel are burned at the same time. Usually, the fuel that is the most abundant or the cheapest is used during production hours, while the other fuel may be used for standby operation.

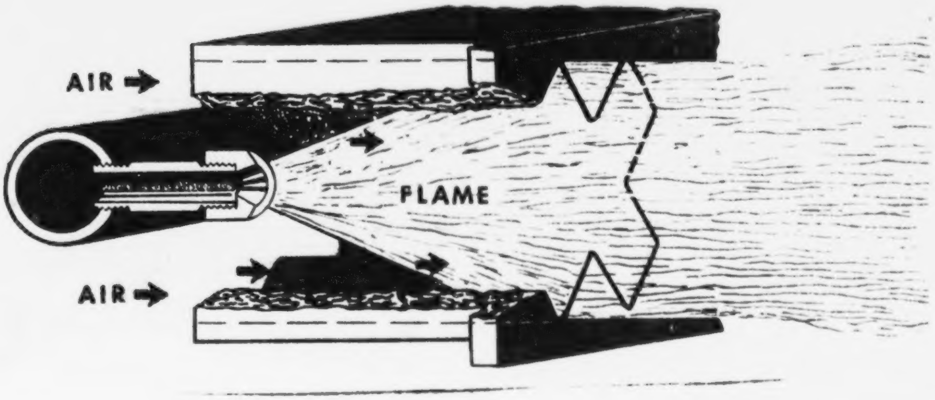

AIR
FLAME
AIR

Figure 1-12. Nozzle-Mixing Gas Burner for Low Pressure

Combination gas and oil burners are usually round in construction as illustrated in figure 1-13a, b, and c. The complete burner may be mounted either in the front or rear of the combustion chamber of the heating unit. Gas or oil burners are connected with unions or flexible tubing so that the burners can be removed or changed easily.

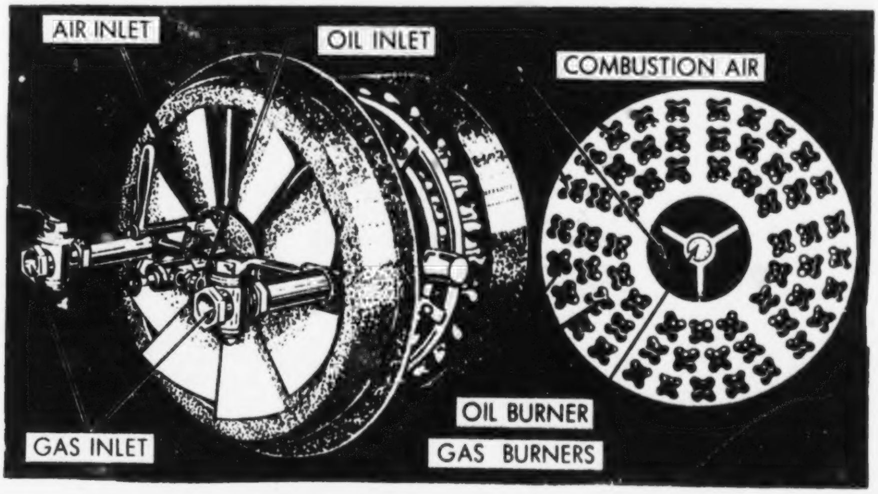

AIR INLET
OIL INLET
COMBUSTION AIR
OIL BURNER
GAS INLET
GAS BURNERS

Figure 1-13a. Combination Oil and Gas Burner

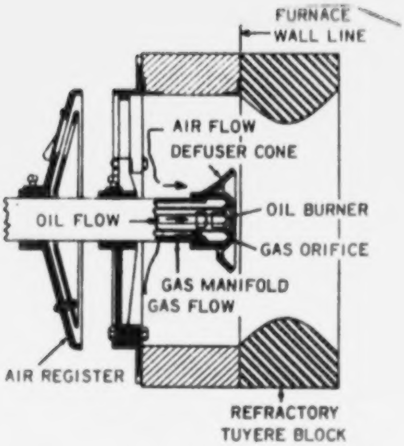

FURNACE WALL LINE
AIR FLOW
DEFUSER CONE
OIL FLOW
OIL BURNER
GAS ORIFICE
GAS MANIFOLD
GAS FLOW
AIR REGISTER
REFRACTORY TUYERE BLOCK

Figure 1-13b. A Register-Type Burner With Gas Orifices Centered in Airstream

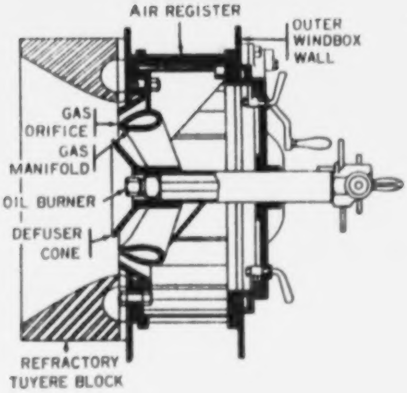

AIR REGISTER
OUTER WINDBOX WALL
GAS ORIFICE
GAS MANIFOLD
OIL BURNER
DEFUSER CONE
REFRACTORY TUYERE BLOCK

Figure 1-13c. A Register-Type Burner With Gas Manifold Dividing Airstream

### Inspection and Cleaning

Gas burners should be inspected, noting the appearance of the gas flame. A yellow flame indicates the air passages are partially restricted, and that carbon is being formed by the resulting incomplete combustion. This carbon must be removed from the flame by adjusting the flow of air.

Inspect the burner orifices, and correct any condition which restricts gas flow or which changes the direction of gas flow.

Examine the interior of the combustion chamber and passages in the heating unit for soot and carbon formation. There should be no formation of soot when burning gas. Such formations indicate poor flame adjustment.

Maintain the main burner flame at a blue color with a yellow tip. It should be stable and not in contact with the burner tiles, ports, walls or boiler tubes. Below are helpful hints in the operation of gas burners.

Directly or indirectly, the pilot light is usually the cause of most inoperative gas burners. Improper positioning of the thermocouple or thermopile and excessive flue and chimney draft conditions account for the greater share of faulty pilot light troubles. The pilot flame should be of sufficient length to heat the thermocouple and ignite the main burner without delay. It should be of a blue color, without a yellow tip. A yellow flame indicates improper combustion and forms soot on the thermocouple insulating it from the heat of the pilot light. A thermocouple must be kept clean, and the proper amount of heat must be supplied to it, in order that it may produce a sufficient amount of electricity to operate either a pilotstat or gas valve. Excessive flue draft draws the pilot light flame away from the thermocouple. This condition causes improper heating of the thermocouple. Also, a short pilot light flame may not heat the thermocouple sufficiently for the thermocouple to produce a current.

## Safety

Observe these safety precautions when starting any gas-fired equipment:

--- Make sure that the room in which the equipment is installed is free from gas. The gas can be accumulated through leakage, accidental opening of fuel valve, and failure of the pilot. Odorized gases can be detected by smell, but many gases are odorless and require the use of an explosion meter or soap solution to *detect them. The meter is similar to those used in detecting the explosive* mixtures in empty gasoline tanks and detecting the presence of a gas in hazardous quantities. All gases used by the USAF for heating are odorized.

--- Inspect gas piping, valves and controls to make sure they are in the best condition and in good working order.

--- The furnace must be purged by establishing an airflow if mechanically handled. In the case of thenatural draft, check the flow of air and determine the presence of any obstructions which may be in the flue and chimney passages.

--- Ignite the burner according to manufacturer's instructions.

## Operating Procedures

### Preliminary Inspection

Make sure the following pre-start requirements are fulfilled:

--- All installation, repair and cleanup work completed.

--- Installation tested for leaks.

--- All combustion safeguard controls, safety controls, programming controls, and combustion-control system components installed, tested and readv for service.

--- Gas supply system, feedwater system and controls, and draft system ready for operation.

--- Condensate drained from gas piping, and piping system purged of air. Correct gas pressure at burner gas header.

### Starting Up Procedures for Large/Small Units

Proceed as follows:

--- Start the indiced-draft fan or open the boiler uptake damper (if applicable).

--- Start the forced-draft fan (if applicable).

--- Purge the furnace and setting for at least five minutes at the rate of one-fourth normal airflow. Open registers of other burners. Adjust furnace draft to about 0.3 inch of water (negative). Set register air pressure at 0.2 to 0.5 inch of water pressure (positive). The best values will have to be determined from experience, since they vary for different installations.

--- Vent the gas burner supply heater through the vent piping until the first burner is in operation. Open vent valve just enough to allow good pressure and flow control by the pressure controllers and automatic valves. Set the pressure in the burner header and the pilot gas header at the correct values for the particular burners and pilots in use.

--- Insert a lighting torch through the lighting port of the burner in the direct path of the gas to be discharged from the pilot burner, or the main burner if a pilot is not used. An adequate torch can be made by wrapping 1/2 inch asbestos rope with wire. Store the torch, remove it from the container and ignite the oil-saturated asbestos. Extinguish the torch by immersing the asbestos-wrapped end in an oil container. Leave torch in this position in container for future use. Never attempt to light one burner from another burner in service or from hot refractory.

--- Open the pilot gas valve and ignite the pilot gas with an electric igniter or a regular torch. After the pilot burner is ignited, open the main gas valve and ignite the main burner gas with the pilot burner.

--- If the main burner does not ignite within ten seconds, or if the torch, pilot or main burner flames blow out, close the burner and pilot gas valves immediately. Before attempting to relight, purge the furnace and setting.

--- After the burner is lit, readjust the airflow and gas flow for correct flame shape, locations and color. The flame should be blue with a yellow tip. It should be stable and should not impinge on the burner tiles, burner parts, rear wall, side wall or boiler tubes.

--- When lighting additional burners, follow the same procedure. Check and adjust header gas pressure as necessary.

Firing Procedure

Important points in the operation of gas register burners are as follows:

--- Control heat airflow by adjusting dampers or changing fan speeds. Use the burner air registers to control flame shape, not the volume of airflow.

--- Adjust the gas-air flow ratio to obtain minimum excess air with zero CO in the flue gas.

--- Maintain a furnace draft of about 0.10 inch of water (negative).

--- Gas supply to the furnace is regulated by the gas pressure. Control firing rate by changing gas pressure or the number of burners in service to meet the demand.

--- Keep individual burner-gass valves wide open. Change burner header pressure by a control valve at the header inlet.

--- Restrict air supply to pilot burners to produce a slightly yellow flame. This flame is stable and is not as likely to go out when subjected to high draft.

Shutting Down

Proceed as follows:

--- Shut off the gas to the burner by closing the individual gas burner valve.

--- Partially close the air register to reduce the airflow as necessary to protect the register and burner parts from overheating.

--- Move the gas burner and ignition cone as far back as the flexible gas hose connection permits.

## Measuring Gas Pressure

It is necessary to set gas pressure at a certain number of pounds per square inch, since a burner may be designed for a specific pressure. Also, it is more economical to use gas at a low pressure providing the heating unit will produce maximum heat. Usually, gas pressure may be adjusted at the pressure regulator.

To determine gas pressure, various vacuum and pressure gauges may be used. Some of the most important gauges are the manometer, Bourdon type gauge and bellows type gauge.

### Manometer

A manometer is one of the simplest types of gauges for measuring pressure. In its simplest form it consists of a bent piece of glass tubing which is partially filled with a liquid. It has a scale for measuring the distances between the levels of the liquid as shown in figure 1-14.

If one end of a tube is connected to one side of the manometer and the other end is connected to the gas line, the pressure of the gas will force the liquid down one side and up the other. You measure the total distance between the two levels. Water is the most commonly used liquid but mercury can be used.

The manometer is an accurate pressure gauge but has its drawbacks due to the possibility of spilling the liquid or of breaking the glass tubes; although, some are made of nonbreakable material. Then, too, manometers are limited as to the range of pressure which can be measured without becoming too unwieldy to handle.

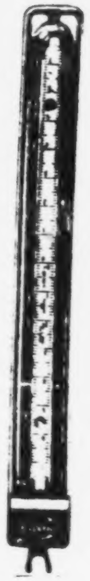


Figure 1-14. Manometer for Measuring Gas Pressure

(Courtesy of The Meriam Instrument Company)

### Bourdon Gauge

The essential element of a Bourdon gauge is an oval metal tube, curved along its entire length to form almost a complete circle. One end is closed and the other is connected to the source of pressure to be measured. The application of pressure to the tube tends to straighten it. This movement is transmitted by suitable linkages to a needle moving over a graduated dial. The dial is calibrated, or scaled, to read directly in pounds per square inch. Figures 1-15 and 1-16.

At lower pressures, that is a few ounces per square inch, the Bourdon tube is not sufficiently accurate for satisfactory measurement. In these cases a guage which utilizes a bellows action is frequently used (Figure 1-17). As the pressure increases, the bellows expands and the hand is caused to move by a linkage connection to the bellows. Likewise, as the pressure decreases, the bellows contracts and the hand moves in the opposite direction indicating a decrease in pressure.

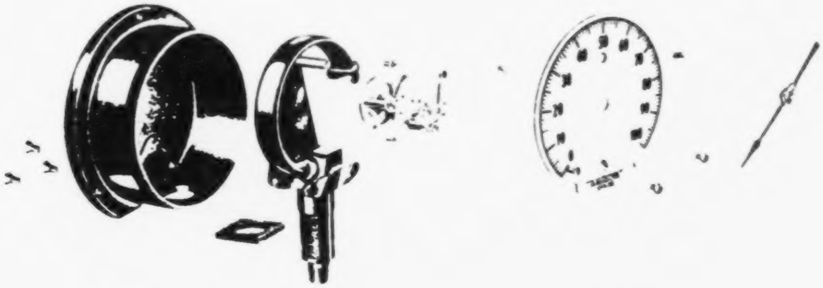


Figure 1-15. Exploded View of Bourdon Type Pressure Gauge (Courtesy of Manning, Maxwell and More, Incorporated)

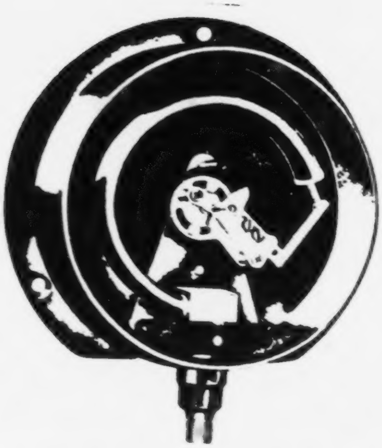


Figure 1-16. Bourdon Type Guage With Face and Hands Removed

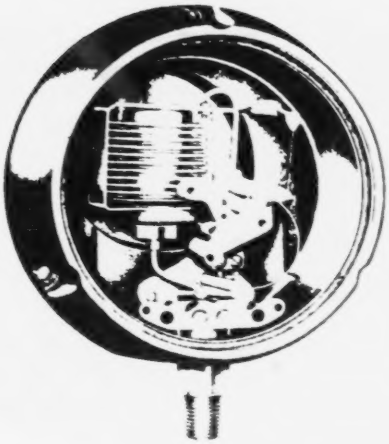


Figure 1-17. Bellows Type Gauge With Face and Hands Removed

(Courtesy of Manning, Maxwell and Moore, Incorporated)

SUMMARY

To summarize, natural gas is probably the most ideal fuel at present. It burns easily, requires simple burning equipment, and burns clean. It is dangerous though, because of the explosion factor. Use extreme caution when working with it.

Gas burners are classified by the pressure of the gas supplied to the burner and by the manner in which the gas and primary air are mixed. There are two basic types of gas burners: the premixing and nozzle-mixing types.

The main controls for a gas burner assembly are a manual gas valve, a pressure regulator, a pilotstat, and automatic gas valve, a pilot light, a thermocouple, and a limit control. Also a thermostat could be considered a part of the gas burner assembly. The automatic gas valve is always the gas burner's primary control.

Installation, maintenance and operating procedures are relatively simple. You usually follow manufacturer's instructions or pertinent local directives. Volumes 1 and 2 of AFM 85-12 also contains some good information.

For a gas burning system to operate properly you must use the proper pressure. This is done by the pressure regulator. If the pressure is not correct you can measure the gas pressure with a Bourdon gauge, Bellows type gauge or a manometer, and adjust the regulator accordingly.

## QUESTIONS

1. Why is natural gas considered an ideal fuel?

2. What is the usual operating pressure for a high-pressure gas system?

3. What does a yellow flame mean?

4. Whose procedures should be followed when removing a gas burner assembly?

5. How is gas pressure measured?

6. What should be done before starting up a burner?

7. What is a pressure regulator and what is its purpose?

8. What is the function of a solenoid gas valve?

9. How does a diaphragm gas valve differ from a solenoid gas valve?

10. What is the function of a pilot light?

11. What units are usually included in an automatic gas burner control system?

12. What does the term "100 percent shutoff" mean?

## REFERENCES

1. AFM 85-12, Volume I, Operation and Maintenance of Central Heating Plants and Distribution Systems.

2. AFM 85-12, Volume II, Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization.

3. AFM 9-16, Maintenance and Operation of Gas Systems.

4. Natural Gas Distribution, a Home Study Course by Southern Gas Association.

# GAS SPACE HEATERS

## OBJECTIVE

To help you understand the different types of gas space heaters and how to inspect, clean and install them.

## INTRODUCTION

Gas-fired space heaters are used for heating requirements whenever gas is available. These heaters are clean in operation, are easily operated, and require no fuel handling. Either natural, manufactured, or liquefied petroleum gases (LPG) can be burned in these units.

## INFORMATION

### Types and Applications of Gas Space Heaters and Their Construction Features

Gas space heaters are made in three categories: room heaters, wall heaters and floor heaters. Room heaters are made both in vented and unvented models, and the other two types are always vented.

### Room Heater

A room heater is a self-contained, free-standing, non-recessed, gas-burning, air heating appliance intended for installation in the space being heated and not intended for duct connection. A room heater may be of either the gravity or mechanical air circulation type, vented or unvented.

UNVENTED. Unvented room heaters should not have an input in excess of 50,000 BTU per hour. Because unvented heaters discharge their products of combustion into the space being heated as well as getting combustion air from the same space, it is essential that they be used in well ventilated space.

VENTED. Vented room heaters (Figure 2-1) are defined as being capable of removing all of the flue gases through a single flue outlet. These heaters may be designed for gravity circulation of air or may incorporate a fan (either factory applied or added as an accessory) for increased air circulation. A vented gas room heater consists of the burner and controls, heat exchanger, draft diverter and outer cabinet. Each component must be connected to a flue or vent.

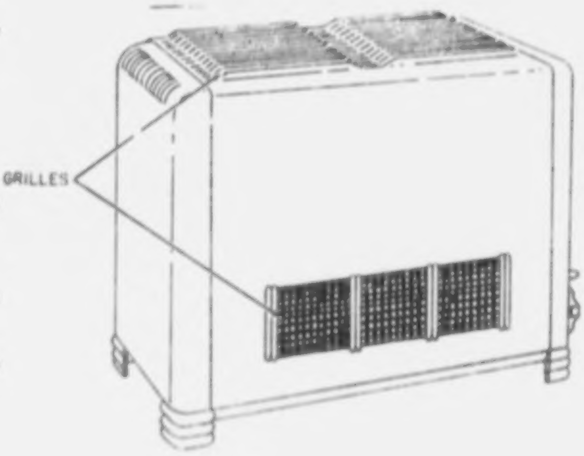


Figure 2-1. A Room Space Heater

### Wall Heater

A wall heater is a self-contained vented heater complete with grilles or their equivalent, designed for incorporation in, or permanent attachment to, a wall, floor, ceiling or partition, and furnishing heated air circulated by gravity or by fan directly into the space to be heated through openings in the casing. Such heaters should not be provided with duct extensions beyond the vertical and horizontal limits of the casing proper, except that boots not to exceed 10 inches beyond the horizontal limits of the casing for extension through walls of nominal thickness may be permitted. When such boots are provided, they should be supplied by the manufacturer as an integral part of the heater and tested as such in accordance with these requirements.

### Floor Heater

A floor heater is a completely self-contained unit suspended from the floor of the space being heated, taking air for combustion from outside this space, and having means for observing flames and lighting the heater from such space. Floor heaters may be either gravity or forced.

## Construction Features

Since gas fired space heaters burn a fuel they must be constructed to transfer as much heat generated as possible. They contain all the necessary controls to burn with gas and they must have a combustion chamber and heat exchanger.

### Burners

The type of burners used in gas space heaters are the atmospheric type and are located in the bottom of the combustion chamber.

### Combustion Chamber

The combustion chamber is where combustion of the fuel takes place. It is called the primary heating surface because this is where much of the heat given off by the burning fuel must be taken off. The remaining heat goes through the heat exchanger.

### Heat Exchanger

The purpose of the heat exchanger is to collect as much of the remaining heat generated and transfer it to the surrounding area. Since it receives what heat the combustion chamber does not take out it is called the secondary heating surface.

### Casing

The purpose of the casing is to act as a sleeve around the combustion chamber and heat exchanger. It provides an airspace to prevent persons from getting burned.

## Procedures for Removing, Disassembling and Reassembling

Like the oil space heater, the variety of gas space heaters manufactured in the United States makes it difficult to state exact procedures for removing, disassembling and reassembling. Manufacturers' instructions should be followed for this type of work.

## Procedures for Inspecting and Cleaning a Gas Space Heater

Gas-fired space heaters should be inspected and maintained according to a schedule prescribed by AF regulations or local directives. The roof jacks and pipe should be examined from the outside as well as the inside of the building. Any noticeable deterioration such as rusting, broken guys, and the like, should be reported.

To clean soot from heaters, take the casing and pipe off and remove gas burner from heater. Some elements can be cleaned by simply tapping the element with a piece of wood to loosen soot, which can then be removed by running a flexible hose from a vacuum cleaner through the unit. If air pressure is to be used to blow out soot, first move heater out of building.

Burners and heating elements also soot-up because foreign matter gets into the venturi tube and interferes with proper flow of gas and air causing the flame to burn yellow. To correct this difficulty, remove venturi tube and burner head and remove obstruction.

Usually, a yellow flame is caused by insufficient primary air. This may be due to improper adjustment at the air mixer or too much lint or other matter being lodged against the opening around the air mixer. Adjust or clean mixer to remedy these difficulties. When venturi or burner is clogged with cooking oil and fats, clean with boiling water.

## Installing Gas Space Heaters

All gas-fired space heaters and their connections must be of the type approved by the American Gas Association (AGA) and must be installed in accordance with the recommendations of the National Board of Fire Underwriters.

The gas pipe used to convey natural or manufactured gas to the space heater is usually black iron pipe. The size of pipe needed depends upon the following factors:

--- Maximum gas consumption of the heater (AGA nameplate rating).

--- Length of pipe and number of fittings.

--- Allowable loss in pressure from building entry to the space heater.

--- Specific gravity of the gas.

Capacity tables for the flow of gas in pipes, in cubic feet per hour, with various pressure drops are available in many handbooks.

Before pipe joints are assembled, all pipe ends should be reamed and pipe dope placed only on the male threads. After piping is assembled, it should be fastened securely to prevent vibration. Care should be taken to test all of the pipe joints with a soap solution after the gas is allowed to flow into the piping.

Care should be taken to properly install the venting system for gas-fired space heaters in order to minimize the harmful effect of condensation and insure that combustion products are carried away by the pipe. Approximately 12 gallons of water are produced by burning 1000 cubic feet of natural gas. The inner surface of the vent must, therefore, be heated above the dew point of the combustion products to prevent water from forming in the flue pipes. Install the vents with the male ends of the inner liner down to return condensation within the pipe on a cold start. Horizontal flue pipes should have an upward pitch of at least one inch per running foot.

Install vents for combustible framing according to pertinent local and Air Force regulations. Construct vents of material resistant to corrosion by flue gas products. Install the same size vent pipe throughout the entire venting system.

NOTE: Never make a vent smaller than the heater outlet.

Each gas-fired space heater should be equipped with a draft diverter or hood, shown in figure 2-2. The diverter is a type of an inverted cone through which the flue gases pass on their way to the chimney. The cone allows air from the heater room to be drawn into the flue pipe along with the flue gases. The purpose of the draft diverter is to prevent a chimney from producing an excessive updraft or downdraft condition. Either condition is apt to extinguish the pilot light or main burner flame.

On new installations, bleed the air from gas piping. To prevent filling the combustion chamber with gas, close the main gas valve on heater and pilot cock. Disconnect pilot tubing outside the heater. Open valve supplying gas to system and air will be expelled through the pilot line.

When all air has been removed from the system, reconnect pilot line. Follow proper sequence of this procedure to avoid accidents.

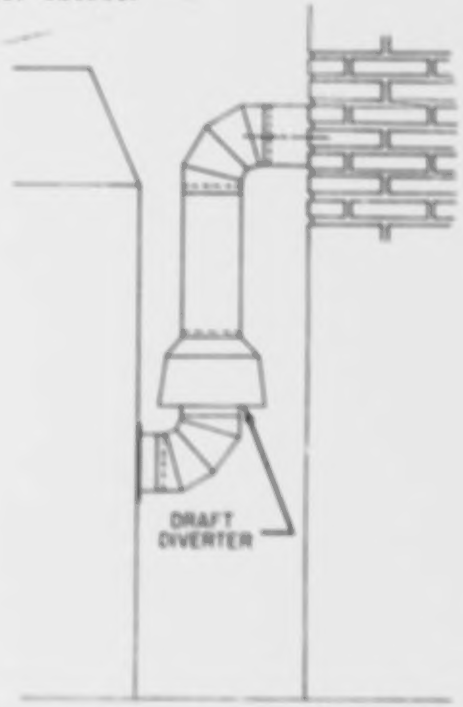


Figure 2-2. A Draft Diverter

To adjust flame, close air mixer to main burner until flame burns yellow, then open shutter on air mixer until the yellow disappears. Insufficient primary air causes flame to burn yellow and results in sooting of the unit when flame strikes the heating unit. Too much primary air causes inefficient operation and will sometimes cause flame to pop back in air mixer resulting in a yellow flame at burner head.

The majority of gas-fired space heaters used by the Air Force are manually controlled. A pilot light is usually provided and the heat turned on or off by a hand-operated valve. If the pilot is extinguished, escaping lighter-than-air gases (natural or manufactured) rise through the vent and dissipate in the atmosphere. Heavier-than-air gases (liquefied petroleum) accumulate in the surrounding space producing a health and fire hazard. For this reason, 100 percent shutoff thermostatic pilots are required on space heaters using liquefied petroleum gas. The term "100 percent shutoff" means that gas flow through the pilot as well as through the main burner is shut off automatically if the pilot light is extinguished--100 percent shutoff is operated from a thermocouple operating a cutoff valve.

### Operating and Adjusting Gas Space Heaters

Gas-fired space heaters are operated according to manufacturer's instructions and pertinent local directives.

## SUMMARY

Gas-fired space heaters are usually used when gas is available at a reasonable price. They are clean in operation and require a minimum of attention. Careful installation of the fuel supply pipes and heater connections is necessary to prevent the hazard of escaping gas. The larger gas-fired heaters require installation of a venting system to cary off the burned gases.

With all heating systems, except small portable gas heaters, a good chimney or vent pipe is essential. To provide proper draft, the chimney or vent pipe connections must be tightly constructed. Horizontal runs of stovepipe must be as short as possible and with a minimum of elbow bends. The vertical height of a chimney must be at least three feet higher than the roof line. Since warm air is lighter than cold air, the warm air (and gases) in a chimney tend to rise. To provide sufficient draft, there must be no restrictions in the upward flow of air.

The units in a gas burner system are usually designed by the manufacturer who will attempt to satisfy the user with his product and its operation by sending the proper literature and, if necessary, a representative to correct any malfunctions.

## QUESTIONS

1. What are the three types of gas-fired space heaters?

2. Whose standards are followed when installing gas-fired equipment?

3. What is used to prevent updraft or downdrafts on a gas-fired space heater?

## REFERENCE

AFM 85-12, Vol II, Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization

# UNIT HEATERS

## OBJECTIVE

To help you to replace, install and maintain unit heaters.

## INTRODUCTION

The most common heating unit that you will be working with are the unit heaters. There are several types of unit heaters and to aid you in learning the principles of operation, this study guide is divided into the following:

--- Types and Application of Unit Heaters

--- Construction Features and Component Parts

--- Controls

--- Procedures for Removing, Installing and Wiring Unit Heaters

--- Operating and Adjusting the Unit Heater

The importance of unit heaters cannot be overemphasized since they are used on all Air Force bases. The information you learn from this study guide will help you both here and in the future.

## INFORMATION

### Types and Application of Unit Heaters

Unit heaters are classified according to their source of heat. Under this classification, there are five types: steam and hot water unit heaters, gas and oil fired unit heaters, and electric unit heaters.

### Steam and Hot Water Unit Heaters

Steam or hot water unit heaters (figure 3-1) are relatively inexpensive but require a boiler and piping system. The unit cost of such a system generally decreases as the number of units installed increases. Therefore, this type of unit heater is most frequently used in new installations involving a relatively large number of units, or on existing systems which have sufficient capacity to handle the additional load. High pressure steam or high temperature hot water units are normally used only in very large installations or where a high temperature medium is required for process work. Low pressure steam and conventional hot water units are usually installed in smaller installations and in those primarily concerned with comfort heating. Steam or hot water unit heaters are chiefly used to heat large, unpartitioned areas or commercial structures, such as: garages, shops, laboratories, stores, base exchanges, and mess halls.

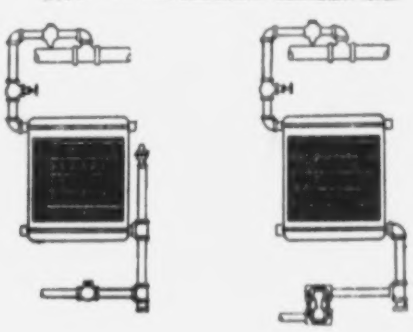


Figure 3-1. Hot Water and Steam Unit Heaters

### Gas and Oil Fired Unit Heaters

Gas and oil fired unit heaters are frequently preferred in small installations where the number of units does not justify the expense and space requirements of a new boiler system, or where individual metering of the fuel supply is required.

GAS FIRED UNIT HEATERS. Gas fired unit heaters (figure 3-2) are usually of the horizontal propeller type or the industrial centrifugal type. Gas fired unit heaters can be used in almost every location where steam or hot water unit heaters are used.

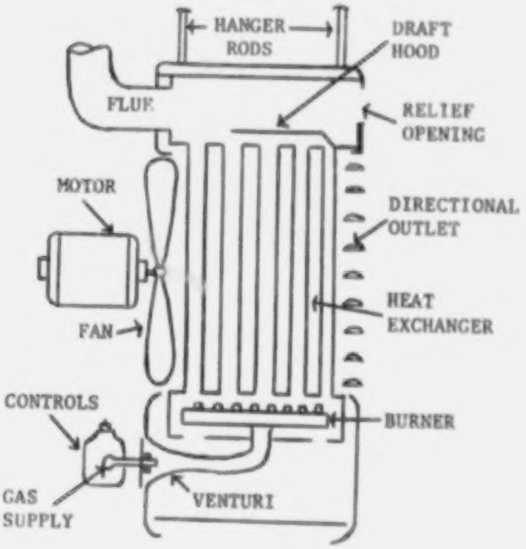

HANGER RODS
DRAFT HOOD
FLUE
RELIEF OPENING
MOTOR
DIRECTIONAL OUTLET
HEAT EXCHANGER
FAN
CONTROLS
BURNER
GAS SUPPLY
VENTURI

Figure 3-2. Horizontal Propeller Fan Unit Heater

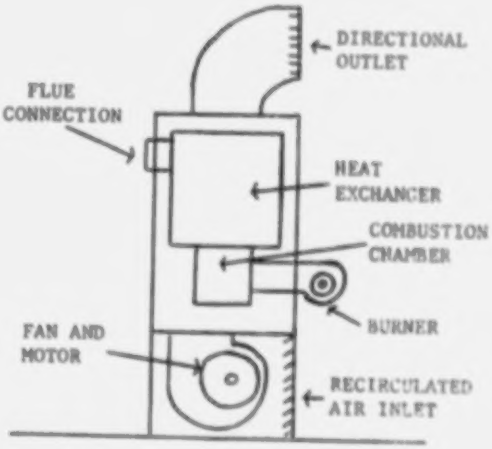

DIRECTIONAL OUTLET
FLUE CONNECTION
HEAT EXCHANGER
COMBUSTION CHAMBER
BURNER
FAN AND MOTOR
RECIRCULATED AIR INLET

Figure 3-3. Oil or Gas Floor Mounted Centrifugal Fan Unit Heater-Industrial Type

OIL FIRED UNIT HEATERS. Oil fired unit heaters are largely of the industrial centrifugal type. Oil fired unit heaters can be used in commercial buildings, industrial plants, shops and garages. (See figure 3-3)

NOTE: Never install an oil or gas fired unit heater in a fuel storage or ammunition storage area. This would be a definite fire hazard.

### Electric Unit Heaters

Electric unit heaters are used where low cost electric power is available, or for isolated locations, intermittent use, supplementary heating, or temporary service requirements. Typical applications are sentry booths, small offices, locker rooms, and isolated rooms scattered over wide areas. Electric units are particularly useful in isolated and untended pumping stations or pits, where they may be thermostatically controlled to prevent freezing temperatures.

## Construction Features and Component Parts

The unit heater is a compact, factory-made assembly. The essential elements of a unit heater are a fan, fan motor, a heating element, and an enclosure.

### Fan

The fan provides circulation of air. The fan can be of the propeller or centrifugal type.

PROPELLER FANS. Propeller fan units may be of the horizontal blow-through type, which blows air through the heating element; or the draw-through type, which draws air through the heating unit. (See figures 3-4 and 3-5)

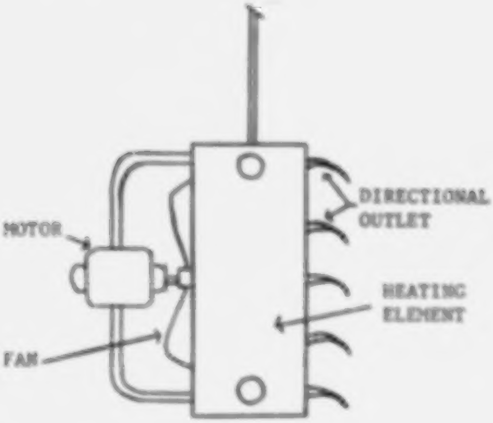

MOTOR
FAN
DIRECTIONAL OUTLET
HEATING ELEMENT

Figure 3-4. Propeller Fan Unit Heater--Horizontal-Blow Type

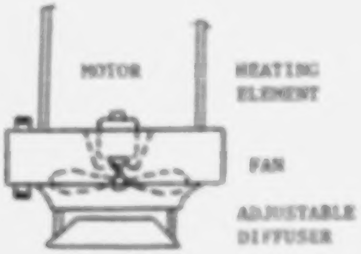

MOTOR
HEATING ELEMENT
FAN
ADJUSTABLE DIFFUSER

Figure 3-5. Propeller Fan Unit Heater--Down-Blow Type

CENTRIFUGAL FANS. Centrifugal fan units may be of the smaller cabinet type as in your small domestic warm air furnaces or larger industrial units which are illustrated in figure 3-6.

### Fan Motor

The fan motor is electric and turns the fan.

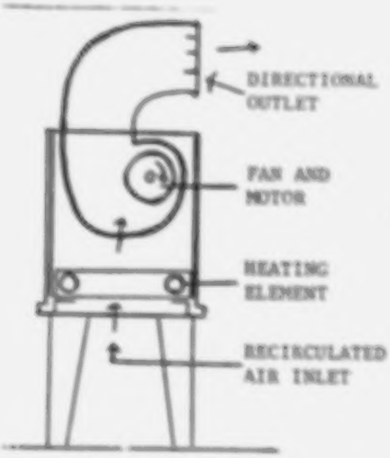

DIRECTIONAL OUTLET
FAN AND MOTOR
HEATING ELEMENT
RECIRCULATED AIR INLET

Figure 3-6. Floor-Mounted Centrifugal Fan Unit Heater--Industrial Type

### Heating Element

The hot water and steam unit heaters use a finned-tube heating element. The oil-fired and gas-fired unit heaters use a heat exchanger. The electric unit heater uses an electric resistance heating element. The heating element gives off heat by radiation.

### Casing

The casing houses all parts and controls of the unit heater.

### Diffusers or Outlet Vanes

The diffusers direct the heated air where it is needed. Usually, they are adjustable so the heated air will not be blown directly on the occupants of the building.

## Controls

### Operating Cycle

A unit heater can be automatically controlled by thermostatic control of fan action or control of the heating-medium flow. Unit heaters which provide both heating and ventilation (see above) usually have a control system to vary the heating and cooling effect while the fans are operating. A room thermostat that controls both a regulating valve and a damper usually provides temperature control. The regulating valve governs the flow of heating medium to the heating element; the damper regulates the ratio of cool outside air to recirculated room air in the air mixture that flows through the heater. The operating cycle of the unit ventilator-heater consists of three main periods.

WARMING-UP PERIOD. The controls provide rapid warming-up. With heating valve wide open and the damper closed to prevent entrance of outside cool air, room air (100%) is recirculated and heated until the desired temperature level is approached.

HEATING AND VENTILATING PERIOD. As the room temperature approaches the desired level, the control system operates the recirculating damper to vary the ratio of outside cool air to recirculated room air. Simultaneously, the regulating valve is throttled to control the heat supply. The combined effect of the damper operation and the throttled regulating valve maintains the desired temperature level.

COOLING AND VENTILATING PERIOD. If the room temperature rises above normal, the room thermostat actuates to completely close the valve. Then, it keeps moving the damper until 100 percent cool air operation is obtained, if necessary. Usually, the unit has control devices which prevent delivery of air cool enough to cause cold drafts. This can be accomplished by an insertion thermostat located in the air stream beyond the heating element. Frequently, the insertion thermostat is set at 60°F and takes control to prevent the discharge of objectionably cold air.

Electric heating control is simple and reliable. Automatic controls usually consist of a thermostat, primary controls, limit controls, and necessary wiring and switching.

## Procedures for Removing, Installing and Wiring Unit Heaters

### Removing Unit Heaters

Unit heaters will be removed according to manufacturer's instructions.

### Installation and Wiring Unit Heaters

INSTALLING UNIT HEATERS. The height at which the unit is mounted affects the air temperature distribution and heater coverage. Proper mounting heights vary with unit designs. However, as a rule, the higher the location, the lower the blow into the occupied zone. With very high locations, it may be necessary to lower the outlet air temperature to force the air into the desired space. Figure 3-7 illustrates the location usually recommended; however, specific recommendations should be obtained from the manufacturer of the individual equipment. Locate unit heaters so that they discharge heated air nearly parallel to exterior walls, in a direction that will produce a rotational circulation around the room. Assure that the air circulates freely to the heater intake.

WIRING UNIT HEATERS. Unit heaters will be wired according to manufacturer's instructions.

SAFETY PROCEDURES. Follow applicable safety with all fuels and electricity. Keep hands away from fans. Do not wear loose clothing and remove watches, rings and other jewelry when working on unit heaters.

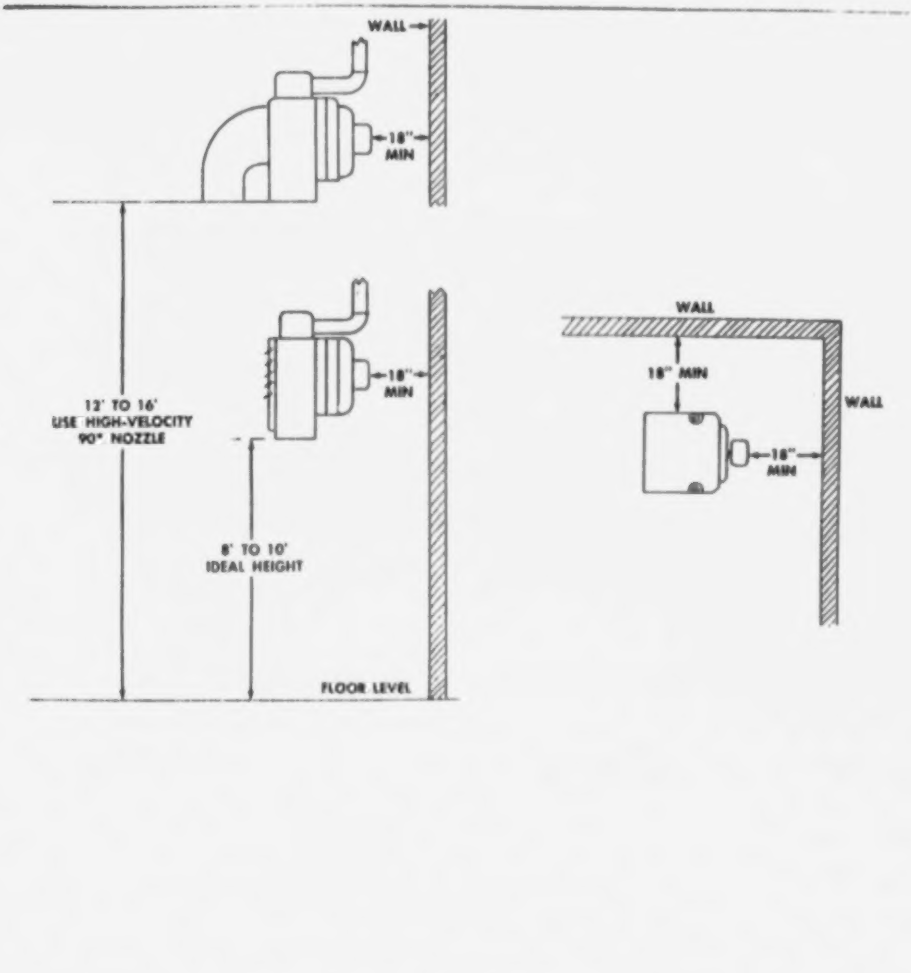

WALL
18" MIN
12' TO 16' USE HIGH-VELOCITY 90° NOZZLE
18" MIN
8' TO 10' IDEAL HEIGHT
FLOOR LEVEL
WALL
18" MIN
WALL
18" MIN

Figure 3-7. Unit Heater Location

## Operating and Adjusting the Unit Heater

### Gas-Fired Unit Heaters

Figure 3-8 illustrates a gas-fired unit heater consisting of the following elements:

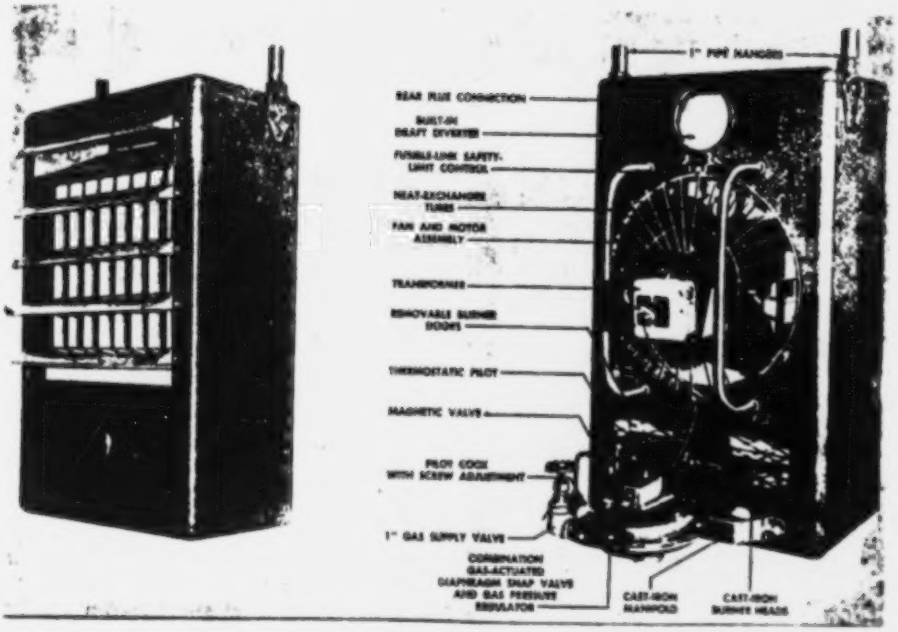

1" PIPE HANGERS
REAR FLUE CONNECTION
BUILT-IN DRAFT DIVERTER
FUSIBLE-LINK SAFETY-LIMIT CONTROL
HEAT-EXCHANGER TUBES
FAN AND MOTOR ASSEMBLY
TRANSFORMER
REMOVABLE BURNER DOORS
THERMOSTATIC PILOT
MAGNETIC VALVE
PILOT COCK WITH SCREW ADJUSTMENT
1" GAS SUPPLY VALVE
COMBINATION GAS-ACTUATED DIAPHRAGM SNAP VALVE AND GAS PRESSURE REGULATOR
CAST-IRON MANIFOLD
CAST-IRON BURNER HEADS

Figure 3-8. Typical Gas-Fired Unit Heater: Front and Rear View

--- Combustion chamber.

--- Atmospheric type gas burners, mounted in the bottom of the combustion chamber.

--- Heat exchanger tubes, acting as radiators and extending from the top of the combustion chamber to the top collecting chamber. They are usually streamlined in cross section for minimum resistance to air flow and maximum heating surface.

--- Top chamber for collecting the products of combustion flowing through the radiators. The products of combustion (flue gases) are conducted to a downdraft diverter and vent (rear flue connection).

--- Motor-driven, propeller-type fan, mounted behind the radiators. Usually, the fan is directly driven by the electric motor and is mounted on its shaft. For low speed application, however, the fan is belt-driven from the motor. Certain types of unit heaters where air must be moved through a duct, or where high air velocities are required, use centrifugal blowers.

--- Combustion and temperature control equipment. These include the thermostat, primary controls, limit controls, auxiliary controls, transformer, etc.

--- Outlet louvers to direct the air stream.

OPERATION. Air for combustion enters the combustion chamber through openings in the bottom (natural convection). At the same time, the fan forces the air to be heated across the radiators, where heat from the combustion products is transferred to the air. The airstream is directed by the outlet louvers, while the flue gases leave the heater through the rear flue connection.

CONTROL. Gas-fired unit heaters have the same controls as other gas units. They include a safety pilot, thermocouple, automatic gas valve, and thermostat. The operating cycle is as follows:

--- When the thermostat calls for heat, it makes a circuit that opens the gas valve. This allows gas to flow into the burner which is lit by the pilot. As the temperature rises in the heater, a thermoelement (preset) makes a circuit to the blower or fan. This fan blows air across the heat exchanger into the space to be heated.

--- As soon as the thermostat is satisfied, the circuit to the gas valve is broken. This causes the valve to close, securing the fire. The fan continues to run until the temperature within the heater drops to the low (fan off) setting.

This is one complete cycle.

## Hot Water Unit Heaters

A unit heater is a heating coil supplied with hot water used to heat a localized area. Coils are usually of the finned type, and air is circulated over them by an electric fan. A unit heater installed in a distribution main is illustrated in figure 3-9.

The maintenance of unit heaters includes a monthly inspection for water leaks, cleanliness of the finned coils, and the operation of the fan motor. Other accessories which should be inspected are the traps, air vents, fan blades, and valves. Repairs should be made accordingly. The electric fan motor should be lubricated monthly.

STARTING UP. Check motor and fan rotation and see that bearings are properly lubricated. Gradually admit hot water to the coils and blow down the unit to remove accumulations of grease and other loose materials found in new piping systems. Start the fan and see that normal speed (revolutions per minute) is carried. After piping is cleaned, supply hot water to the coils by proper valve operation.

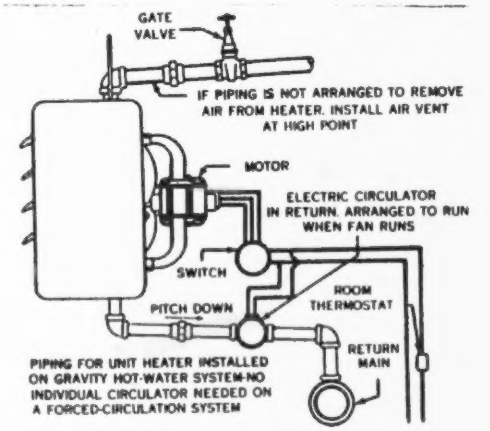

GATE VALVE
IF PIPING IS NOT ARRANGED TO REMOVE AIR FROM HEATER. INSTALL AIR VENT AT HIGH POINT
MOTOR
ELECTRIC CIRCULATOR IN RETURN. ARRANGED TO RUN WHEN FAN RUNS
SWITCH
PITCH DOWN
ROOM THERMOSTAT
RETURN MAIN
PIPING FOR UNIT HEATER INSTALLED ON GRAVITY HOT-WATER SYSTEM-NO INDIVIDUAL CIRCULATOR NEEDED ON A FORCED-CIRCULATION SYSTEM

Figure 3-9. A Unit Heater for a Hot Water Heating System

NORMAL OPERATION. Maintain adequate flow of water at a correct temperature to develop rated capacity. Check motor and fan operation for excessive noise and abnormal vibration and temperature. If spaces fail to heat satisfactorily, check the following:

Motor Speed. A unit running at a speed below normal, delivers less air. See that heated air is passing through the unit in sufficient quantity to deliver rated capacity.

Water Flow. Make sure correct amount of water is flowing through the coils to fulfill capacity requirements. See that all required valves are open, that the coils are free of air pockets, and that there is no obstruction or stoppage of flow. Check water pressure.

Water Temperature. Water supplied to the unit should be at rated temperature.

Space Heat Loss. If the unit is delivering its intended capacity, check the space heat loss and see if it exceeds the capacity of the heater.

Location of Heater. There are horizontal and vertical distance limits in the location of heaters. Location affects flow and coverage of the unit. Check manufacturer's instructions and charts.

Shutdown. Proceed as follows:

--- Close the water inlet to the unit.

--- Stop the motor.

--- Drain the unit if there is danger of freezing.

Steam Unit Heaters

Unit heaters used in steam heating systems, shown in figure 3-10, are similar to those used for hot water heating. Steam enters the unit heater at the top and gives off heat to the finned tubes of the radiator. The circulating fan forces the air to be warmed through the finned tubes and at the same time, causes the air to circulate in the space to be heated.

STARTING UP (NEW INSTALLATION). Check motor and fan rotation and see that bearings are properly lubricated. Gradually admit steam to the coils and blow down the unit to remove accumulations of grease and other loose materials found in new piping systems. Start the fan and see that normal speed (revolutions per minute) is carried. After piping is cleaned, supply hot water to the coils by proper valve operation; assure that the steam trap is working correctly; and see that air is being vented properly.

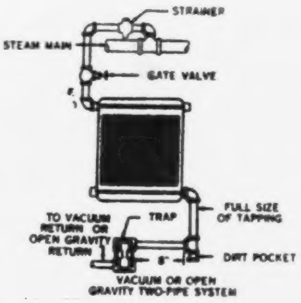

STRAINER
STEAM MAIN
GATE VALVE
FULL SIZE OF TAPPING
TRAP
TO VACUUM RETURN OR OPEN GRAVITY RETURN
8"
DIRT POCKET
VACUUM OR OPEN GRAVITY TWO-PIPE SYSTEM

Figure 3-10. Unit Heater Installation Diagram

NORMAL OPERATION. Maintain adequate steam flow at correct pressure to develop rated capacity. Check operation of steam trap and air vent. Check motor and fan operation for excessive noise and abnormal vibration and temperature. If spaces fail to heat satisfactorily, check the following.

Speed of the Motor. A unit running at a speed below normal delivers less air. See that heated air is passing through the unit in sufficient quantity to deliver its rated capacity.

Steam Flow. Make sure that the proper amount of steam to fulfill capacity requirements is flowing through the coils at the correct pressure. See that all required valves are properly open, that the coils are free of air pockets, and that there is no obstruction or stoppage of the flow.

Water Pressure. The steam supplied to the unit should be at rated pressure. This will determine the steam temperature.

Space Heat Loss. If the unit is delivering its intended capacity, check the space heat loss and see if it exceeds the capacity of the heater.

Location of Heater. There are horizontal and vertical distance limits in the location of heaters. Location affects blow and coverage of the unit. Check manufacturer's instructions and charts.

SHUTDOWN. To shut down a steam unit heater, you should proceed as follows:

--- Close the steam inlet to the unit.

--- Stop the motor.

SUMMARY

Unit heaters are probably the most efficient piece of heating equipment there is. They are a factory-make assembly, compact, easily installed, and easily controlled. There are five main types: steam, hot water, electric, oil and gas fired. Unit heaters have five main parts: the fan, fan motor, heating element, casing and diffusers.

QUESTIONS

1. What are the five types of unit heaters?
2. What type of unit heaters require a boiler and piping system?
3. Where are steam unit heaters mainly used?
4. What types of unit heaters will be used when individual metering of the fuel supply is required?
5. What are some typical locations for electric unit heaters?
6. What is the casing used for?
7. How are unit heaters wired?
8. What are the five basic parts of a unit heater?
9. What are the main controls on a unit heater?
10. What types of unit heaters cannot be used in a fuel or ammo storage?

REFERENCE

AFM 85-12, Volume II, Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization

# FORCED WARM AIR HEATING SYSTEMS

## OBJECTIVE

This study guide will help you maintain a warm air furnace, replace the electrical controls and maintain a forced warm air system.

## INTRODUCTION

During the last forty or fifty years as standards of living continued to improve, people began to demand better and more efficient heating systems for their homes and their places of business. They were no longer satisfied with a stove or a fireplace in each room. Instead, they wanted some type of a large heating unit or system that could be used to heat all the rooms in a house or building from just one fire. One of the first steps taken to fill this demand was the development of the warm air heting systems. In these systems, the furnace is located at one central point, usually the basement of a house; and the air heated by this furnace is carried to the various rooms and parts of the house by warm air ducts.

This study guide will provide you specific information concerning warm air heating under the following main topics.

--- The Purpose of a Warm Air Furnace

--- Types of Warm Air Furnaces

--- Construction Features

--- Removing, Disassembling and Reassembling Procedures

--- Inspecting and Cleaning Procedures

--- Installation Procedures

--- Types and Functions of Furnace Automatic Controls

--- Removing, Inspecting and Cleaning Automatic Controls

--- Installing, Wiring and Operating Automatic Controls

--- Operating Procedures

--- Types of Warm Air Heating Systems

--- Types of Warm Air Distribution Systems

--- Construction Features

--- Inspecting and Cleaning Heating Ducts

--- Inspecting and Adjusting Distribution Dampers and Linkages

--- Removing and Cleaning Filters

--- Blower Maintenance

INFORMATION

## The Purpose of a Warm Air Furnace

The primary purpose of warm air furnaces is to burn fuel efficiently and to transfer the heat generated to the circulating air. Warm air heating systems are either gravity type or forced-air type. Many satisfactory types and arrangements of heating surfaces are manufactured. Most furnaces consist of a combustion chamber or primary heating surface, and a heat exchanger or secondary heating surface. Available records indicate that the heat transfer per square foot of heating surface is practically the same for cast iron and steelplate when both are subjected to the same temperature difference. With either cast iron or steel, thicker metal means longer life without materially affecting the heat transfer.

## Types of Warm Air Furnaces

### Cast-Iron Furnaces

Generally, the minimum thickness of cast-iron furnace sections is 1/2 inch. These furnaces resist corrosion and high temperature and, because of their relatively large mass, have a large heat-storage capacity. This latter characteristic gives them a flywheel heating effect. However, they are slow to respond to heat changes. Cast-iron furnaces are constructed in sections, made gastight by liberal use of furnace cement, asbestos rope, or both. The heat exchanger is usually located on top of the combustion chamber. Cast-iron furnaces are normally used with gravity systems.

### Steel Furnaces

The metal parts of steel furnaces are joined by riveting, welding or both. Because of their relatively small mass, they can deliver heat rapidly on demand, and can adapt to fast changes in heat requirements. However, their heat storage capacity is rather small. Steel furnaces are made of heavy-gauge steel and are riveted and caulked or welded at the joint to make them gastight. The fronts are usually cast iron. Small steel furnaces usually have a single heat exchanger attached to the rear of the combustion chamber. In larger sizes, two heat exchangers may be installed on the furnace sides. There are two types of steel furnaces: horizontal and vertical. Vertical furnaces may be either up-flow or counter-flow.

HORIZONTAL. In the horizontal furnace, the fan, filters and heat exchanger are aligned in a horizontal position. Since this furnace can be suspended from the ceiling, or installed in attics or crawl spaces, it takes up little or no floor space.

VERTICAL. The vertical furnace has the same components as the horizontal, but is designed for floor installation. There are two types:

--- The vertical up-flow furnace.

--- The vertical counter-flow furnace.

Vertical Up-Flow. On the vertical up-flow furnace, the fan is located in the bottom of the furnace. This type furnace is normally used with either the wall or ceiling delivery distribution system. The furnace could be located in a house or building with a basement; but mor than likely, in a house or building without a basement.

Vertical Counter-Flow. On the vertical counter-flow furnace, the fan is located at the top of the furnace. This type furnace is specifically designed for houses or buildings without basements. The heat registers will be located in the floor or possibly the walls.

Warm air furnaces can be made to burn coal, fuel oil or gas. The most common types today are the gas-fired and oil-fired furnaces.

## Construction Features

### Heat Source

The heat source is a furnace unit which generates by burning fuel. Basically, a warm air furnace consists of combustion chamber (primary heating surface), a heater exchanger section (secondary heating surface), and a casing. The furnace may be cast iron, steel or a combination of the two. It may be fired with any of the common fuels.

### Combustion Chamber and Heat Exchanger

The combustion chamber, as a primary heating surface, absorbs heat from the fire, chiefly by radiation. The heat exchanger section, as secondary heating surface, absorbs heat from the furnace gases by conduction.

### Casing

The casing completely encloses the furnace assembly. It forms a space through which air is circulated (by natural or forced convection) and warmed by contact with the hot exterior surfaces of the combustion chamber and radiator.

## Removing, Disassembling and Reassembling Procedures

The variety of furnaces manufactured in the United States makes it difficult to state exact procedures for removing, disassembling and reassembling. These procedures should be acquired from the manufacturer of the furnace you are working with.

## Inspecting and Cleaning Procedures

Warm air furnaces should be inspected and maintained according to a schedule prescribed for such furnaces by AFRs or local command. The roofjacks as well as the smoke pipes should be inspected from the inside as well as the outside of the building. Any noticeable deterioration, such as a rusted hood, roofjack or flue pipe should be replaced. The roofjack guys should be replaced if badly rusted. The chimney must be checked for cracks and holes. These should be repaired in order to prevent air leaks. When cold air enters the chimney and dilutes the warm air, it reduces the draft. All soot and fly ash must be removed from the chimney and flue cleanouts. Inspect the draft dampers for proper operation. Check the draft diverter for soot accumulation.

Check the heat exchanger surfaces for warping and rusting. Replace these units if they are unserviceable. Check the firebox doors, door hinges and latches for damage. Replace any broken parts. Seal all the casing joints and asbestos type of caulking compound. Check the grouting around the base of the furnace and repair it if necessary.

Completely clean the furnace heat exchanger and the flue pipe surfaces with a vacuum cleaner.

Inspect the furnace room for cleanliness. Notify your superior of any combustible material such as rags, papers and boxes. See that the performance chart is posted and readable.

## Installation Procedures

Warm air furnaces shuld be installed in conformance with procedures or methods prescribed, according to diagrams applicable to each type of equipment furnished by the manufacturer.

The base electrical shop should be responsible for installing all line voltage wiring. The heating specialist should only install line or low voltage automatic control equipment. The term low voltage applies to equipment operating on, or wiring carrying 50 volts or less.

Since there are many types and makes of oil and gas fired warm-air furnaces on the market, the detailed assembly instructions to suit all makes and types cannot be published in this book; however, the following instructions apply to all gravity warm-air furnaces.

Study the assembly instructions included with each furnace thoroughly and follow these instructions exactly. Each piece of casting is manufactured to fit in its proper place. Parts of one type of furnace are seldom interchangeable with other types of furnaces.

Install furnaces in a level position on a solid masonry base. Do not install the furnace on a base constructed of wood or other combustible material. If the masonry base is uneven, use steel or cast-iron wedges (shims), or the leveling bolts that are provided. Always use a spirit level to make sure the unit is level.

Provide enough clearance to permit easy access for repairs. Allow a space of at least 18 inches between the furnace and a wall constructed of wood or other combustible material. It is a good practice to install asbestos boards on a wooden wall next to a furnace. This will help to reduce the fire hazard. With masonry walls, units may be installed nearer the walls; however, leave ample room to permit proper servicing.

Special attention should be given to ceiling clearance. Cover the ceiling over the furnace with asbestos sheets or asbestos paper if the top of the furnace is close to the ceiling.

Furnace cement is furnished with each cast-iron furnace. Seal all joints with a liberal amount of furnace cement between sections to insure that the furnace is gas-tight. Asbestos rope is furnished with a number of furnaces for certain applications. Follow manufacturer's instructions covering its use. See that projections from furnace such as smoke pipe or cleanout doors extend through outside of casing.

In assembling a furnace, exercise care in tightening all bolts. Draw each bolt until almost tight. Then after all bolts have been installed, draw each one gradually until all are uniformly and properly tight. Avoid drawing bolts too tight, as this will crack or break a casing or buckle a steel plate.

After assembling furnace, check all doors for free operation and tight fit. Install firebrick in accordance with manufacturer's instructions.

Install furnace casing, bonnet and gravity-return air shoe in accordance with the manufacturer's instruction. Fit or fasten casing or panels securely. If interlocking, see that they are properly in place and are airtight. If a bottom floor panel (gas or oil) is not furnished, grout casing to make it airtight by chipping and wetting the floor and using a liberal amount of cement mixture. If a circular casing is used, strip joints with asbestos paper to make them airtight. Asbestos rope or a draw band collar is furnished to make the connection between flue and cleanout airtight. If baffles are furnished or recommended, install them in accordance with manufacturer's recommendations. In installing baffles, exercise care to provide proper distribution of air over combustion chamber and heat exchanger.

Install downdraft diverters furnished with the equipment on all gas burning furnaces. Diverters are developed for individual furnaces. Never use diverters made by a local manufacturer unless thely have been calibrated for the specific heating unit.

NOTE: Check heat exchanger before installation for leaks or cracks.

Use vent or smoke pipe which is at least as large as the smoke pipe outlet of the furnace. Securely fasten the vent or smoke pipe at each joint with a minimum of three sheet metal screws. Install all horizontal pipes with a pitch of at least one inch per linear foot.

A good chimney can be built of steel, brick or other material approved by the office of the Civil Engineer. The chimney should have a cross-sectional area equal to or larger than the flue outlet of the furnace. The smaller dimension of a rectangular chimney must be at least 2/3 of a furnace flue diameter. The area of a chimney must be increased 4 percent for each 1000 feet of altitude. Equip the chimney with a soot and dirt cleanout at the base. The upper part of the chimney is usually constructed of a metal section terminating with an appropriate hood. Follow the manufacturer's recommendations on chimney height. Never build a chimney less than 25 feet in height, unless it has blower-assisted draft and then never less than 18 feet. Always extend a chimney at least three feet above the peak of the roof.

Ventilate the furnace room adequately to supply air for combustion. Provide an opening having one square inch of free air area for each 1000 BTU per hour of furnace input rating with a minimum of 200 square inches. Locate opening at or near the floor line whenever possible. In addition, provide two louvered openings having free-air area of at least 200 square inches each in, at or near the ceiling as near opposite ends of the furnace room as possible, as to expel flue gases.

## Types and Functions of Furnace Automatic Controls

Automatic controls are used on heating systems to accomplish one or more of the following:

--- Insure required conditions of temperature, pressure or humidity.

--- Provide safety protection by preventing operation of mechanical equipment when such operation would be harmful or hazardous.

--- Insure economical results by providing steady-state conditions and preventing excessive operation of the system.

--- Eliminate human error in heating equipment control.

The main elements of a temperature control system are primary control, limit control, thermostat and auxiliary controls. These controls were covered in an earlier lesson but we will review each.

### Primary Controls

Primary controls are actuating devices which operate hand-fired plants in response to signals received from thermostats. Often the primary control is a simple switching device which closes and opens the main circuit (electric systems). The primary control for gas heating is the automatic gas valve and for oil heating, the stack switch and protector relay perform this function.

### Limit Control

The limit control is a device that responds to temperature changes in the warm air heating systems. The limit control is wired in series to the primary control. This control will break the circuit to the primary control, which will shut down the burner, whenever the temperature in the furnace becomes excessive. It is installed in the bonnet of the furnace. The wiring should conform to local electrical ordinances. No lubricating oil should be used on the internal mechanism, and the cover should be in position at all times. When trouble is experienced with the unit, it should be replaced. This control is normally closed (NC) which opens on a temperature rise. Set the limit control to stop the firing equipment when the air temperature reaches 175° to 200°F.

### Blower Control (Fan Switch)

The fan switch controls the operation of the blower motor in a forced warm air heating system. The fan switch starts the fan motor when the air in the furnace bonnet rises to a predetermined temperature to be circulated in the rooms. The fan switch is installed in the bonnet of the furnace. Set the fan switch to stop when the plenum temperature is 5° to 10°F above maximum thermostat setting. The starting temperature should be 15° to 25°F above the stopping temperature, with a minimum differential setting of about 15°F. These settings will depend on the climate and type of systems.

NOTE: Always follow manufacturer's recommendations when differences occur between their settings and these.

### Combination Control

(One housing is used for the high limit and fan control.) Settings may be adjusted or factory set and sealed. Operation of controls are the same as if they were used as an individual. Responses are transmitted normally from a helix (bimetal) coil which reacts to changes in temperature. On some combination controls, manual control of the fan is possible. For installation procedures, follow the manufacturer's instructions on wiring and setting.

## Thermostat

The thermostat is the nerve center of the heating-control system. It is a sensitive unit that responds to changes in room temperature, and it indicates whether more or less heat is required from the heating unit. It transmits the indicating signal to a primary control for action. This is done by closing or opening an electrical contact within the thermostat.

Thermostats often differ in construction according to the type of primary control with which they are used. Probably the commonly used thermostats are the spiral-bimetallic type and mercury-bulb type.

## Humidity Controls

Water vapor in the atmosphere is called humidity. There is a limit to the amount of water vapor that a pound of dry air can hold at a fixed temperature. When this limit (saturation) is reached, the relative humidity of the air is 100 percent. Since it cannot hold additional moisture, any water vapor introduced to the air after saturation is dropped through condensation.

To prevent excessively low relative humidity inside an operating heating system, the air can be humidified. Figure 4-1 illustrates a typical humidifier of the kind used with older model warm-air furnaces at some Air Force installations. Humidifiers are usually installed in the warm-air plenum chamber. A needle valve is actuated by a float to maintain a given level of water in a pan. Hot, dry air from the furnace absorbs (evaporates) the water from the pan, thereby increasing its relative humidity. (Be sure to check installation of the pan to see that it does not overflow on the combustion chamber or furnace radiator.) This type of humidifier does not provide close control of relative himitidy conditions.

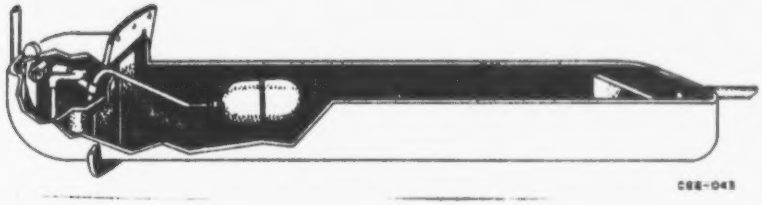


Figure 4-1. A Typical Pan Type Humidifier

Humidifiers are usually standard equipment with almost all types of warm-air furnaces. Humidifiers for warm-air furnaces are usually the pan type (figure 4-1). Unless the water used is comparatively free of solids, these units require frequent attention, since the float can stick in the open position or the valve may clog. Overflowing of the pan due to valve stuck in open position can result in a cracked heating section, and a clogged inlet valve will make the humidifier inoperative.

Humidistat

A humidistat senses the relative humidity of the air in a space or system. It is designed with sensing elements made of wood, hair or animal membrane.

Under normal operating conditions, the humidistat will sense humidity within 1 percent relative humidity. A humidistat sends electrical signals to operate dampers, valves or other devices that control relative humidity. For example, when a humidifying device, having a spray nozzle is used, a solenoid valve is installed ahead of the nozzle. The humidistat in the conditioned space automatically energizes the solenoid when the relative humidity drops below the humidistat setting. As soon as the humidity in the conditioned space is brought up to that needed to satisfy the humidistat, the circuit is opened and the solenoid shuts off automatically.

The humidistat is a very delicate instrument and must be handled with care. Keep the instrument encased at all times and free of dust and other foreign materials. See that it is mounted securely. Locate it where there is a good circulation of air around its sensing element.

## Removing, Inspecting and Cleaning Automatic Controls

The procedures for removing, inspecting and cleaning automatic controls will be supplied by the manufacturer of the controls.

## Installing, Wiring and Operating Automatic Controls

### Installing

Proper care in handling and installing controls will assist in obtaining good performance form a warm-air heating system. Brochures are available on installation of controls from each manufacturer and should be followed while working with these controls. Always be sure that a control is correctly wired. Many malfunctions are attributed to not adhering to this general principle. All control terminals are usually colored, lettered or numbered, and the manufacturers furnish wiring diagrams which are simple and easy to follow.

THERMOSTAT. Always install a thermostat on an inside wall at eye level and in a place where it will be affected by average room temperature.

Make sure there is free circulation of air at the point of mounting and that the thermostat is unobstructed by furniture, doors and the like. Do not mount the thermostat where it will be affected by drafts from hallways or stairways or where it will be affected by the warm-air stream from air registers. Do not install thermostats close to concealed warm or cold water pipes, warm-air ducts, or on furnace room walls. Always install a thermostat away from the sun's rays, because the radiant heat from the sun will cause a shifting of the control point.

LIMIT CONTROL, BLOWER CONTROL AND COMBINATION CONTROL. The same fundamentals of installation apply to all three of these controls. In installing these controls, insure that in the operating position, no portion of the actuating elements touch the crown sheet. Install these elements so that the effects of radiant heat are kept to a minimum. Install the controls so that they will be subject to rapid changes in temperature of the furnace. Do not install the control elements where they will be affected by cold air returns or where circulation of air around them is restricted by baffles or deflecting fins.

Use a swivel mounting bracket if space permits. If a control must be mounted flush on furnace, be sure that an asbestos insulator, 1/2 inch thick, if possible, is placed between furnace and control. It is important to limit temperature inside the control to 150°F, if possible, to prevent damage to switches and maintain electrical rating of load contacts.

Under no circumstances should fan load rating of control be exceeded. For maximum efficiency and comfort, fan control setting should be as low as possible without discharge of cold air. For most installations, a limit control setting of 175°F to 200°F is satisfactory. After installation of these controls, as all controls, replace the cover. This protects the mechanism and discourages unauthorized tampering with the settings.

## Wiring Procedures

A typical wiring diagram for a gas-fired warm air furnace using line voltage is shown in figure 4-2.

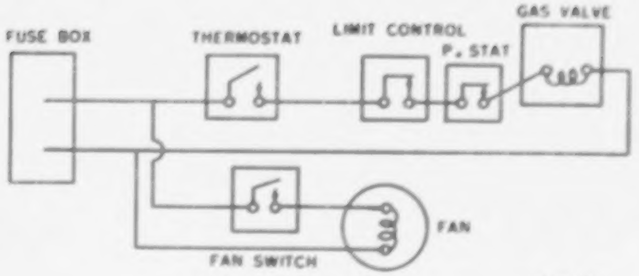

FUSE BOX
THERMOSTAT
LIMIT CONTROL
P. STAT
GAS VALVE
FAN
FAN SWITCH

Figure 4-2. Line Voltage Circuit

A typical wiring diagram for a gas-fired warm air furnace using low voltage is shown in figure 4-3.

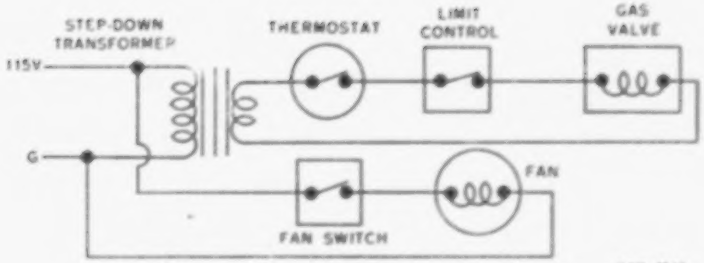

STEP-DOWN TRANSFORMER
115V
G
THERMOSTAT
LIMIT CONTROL
GAS VALVE
FAN
FAN SWITCH

Figure 4-3. Low Voltage Circuit

A typical wiring diagram for oil-fired warm air furnaces is shown in figure 4-4.

Use all applicable precautions whend working with the different types of fuel. Also observe all safety rules when working on the electrical controls and wiring of a warm-air furnace.

NOTE: Remove all watches, rings and other metal jewelry when working on furnaces; also, fatigue shirts must be tucked in.

When working on oil-fired furnaces, any oil spilled must be wiped up immediately.

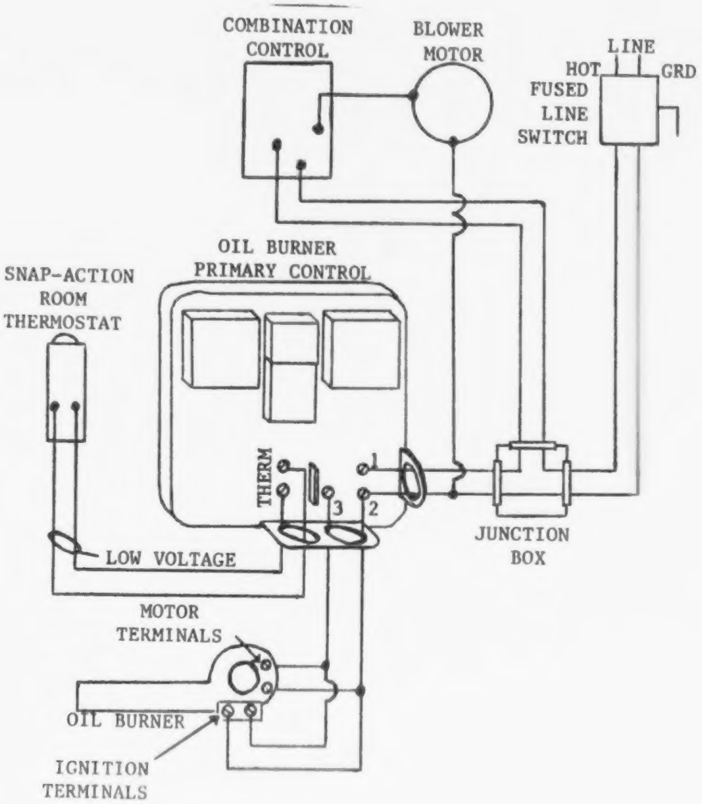

COMBINATION CONTROL
BLOWER MOTOR
LINE
HOT
GRD
FUSED LINE SWITCH
OIL BURNER PRIMARY CONTROL
SNAP-ACTION ROOM THERMOSTAT
THERM
1
3
2
JUNCTION BOX
LOW VOLTAGE
MOTOR TERMINALS
OIL BURNER
IGNITION TERMINALS

Figure 4-4. Warm Air, Oil-Fired Cotnrol Circuit

### Operating Procedures

Before placing any new, reconditioned or inactive warm air heating system into service, carefully inspect its installation. Learn the purpose and location of every piece of equipment and control; this knowledge will help prevent future outages.

Pre-Startup

Before starting up the system, make sure that the following requirements are fulfilled:

FORCED WARM-AIR FURNACE

--- All installation, repair and cleanup work completed.

--- All air and gas ducts and passages tight and free from obstructions; gas and air control dampers in good operating condition.

--- All ducts tested for leaks, and insulated if necessary.

--- Combustion chamber, radiator and casing tested for leaks. Testing procedures are outlined in AFM 85-12, Volume II.

--- Air filter clean. Humidifier filled with water and ready for operation.

--- Forced air blower and motor in good operating condition, properly lubricated; rotation and speed tested.

--- All auxiliary equipment required to operate the furnace properly installed and ready for operation; e.g., fuel-burning system, draft system, combustion control system, etc.

--- All meters, instruments and gauges properly installed, calibrated and ready for operation.

--- All access and observation doors closed.

AIR DISTRIBUTION SYSTEM

--- All installation, repair and cleanup work on air supply ducts, trunks, branches, regulating dampers, diffusers, grilles, etc., completed. Ducts properly insulated, if required.

--- All installation, repair and cleanup work on air return ducts, grilles, etc., completed. Ducts properly insulated, if required.

CONTROL SYSTEM

--- All installation, repair and cleanup work completed.

--- Thermostats and primary, limit and auxiliary controls properly calibrated and preset to operate within approved limits.

FIREFIGHTING EQUIPMENT. Make sure that fire extinguishing equipment is conveniently located and ready to operate and that personnel know how to use it and have definite instructions on firefighting procedures.

Starting Up

Proceed as follows:

--- Close all dampers located in the various warm air and return air ducts and at the registers.

--- Light off the furnace under manual control.

--- Start the blower under manual control. Adjust air regulating dampers to produce even temperature distribution between rooms.

System Adjustment

To obtain better results, and more even room temperatures, adjust the controls of forced warm air heating system for as nearly continuous blower operation as possible, by setting the room thermostat to control the firing, and the blower control to control the blower operation. Take the following steps to adjust the system:

--- Set room thermostat at the desired room temperature. This is the operating control that starts and stops the firing and draft equipment.

--- Check the fuel input in relation to the heat loss of the building. In gas-fired installations, see that orifices in the spuds are large enough for the kind of gas used and the type and capacity of the installation. Adjust manifold pressure. For coal-fired and oil-fired installations, check capacity and operating range of stoker and burner. When the system operates, make sure that fuel-air ratio is correct and that firing and draft equipment are adjusted for proper firing rate at the highest practical efficiency.

--- Adjust blower air volume to produce an air temperature rise through the furnace of about 90°F, by regulating outlet air dampers or changing the blower speed.

--- Set the blower control to stop when the plenum temperature is 5° to 10°F above maximum thermostat setting. The starting temperature should be 15°F to 25°F above the stop setting. Use the lower settings for high sidewall registers and the higher settings for the baseboard registers. In general, coal-fired installations should use the higher settings; gas or oil-fired installation, the lower. For very long ducts and in very cold climates, it may be necessary to use slightly higher blower cutout points; however, this point should be set as low as practicable.

--- Set the high limit control (in the bonnet of the furnace) to stop firing equipment when the air temperature reaches 175°F to 200°F, regardless of room thermostat requirements. The average air temperature rise through the furnace should be from 80° to 100°F when it operates in very cold weather.

--- When the blower speed is changed to adjust the airflow through the furnace, be sure that the operating speed does not overload the motor or cause undue noise. Refer to AFM 85-12, Volume I, for information on speed reducers.

--- Balance the system by regulating damper openings to obtain an even temperature distribution in all rooms. Check air velocities at warm air register outlets with an anemometer or velometer (see AFM 85-18, para CI, 07). Regulate register air velocities to obtain about 50 feet per minute at a point three quarters of the distance from the register to the opposite wall. Regulate flow by damper adjustment. For better system balance, it is sometimes necessary to change blower speed. Refer to para 46f, Volume I, AFM 85-12 for information on fan output control. See also Section J, Chapter 2, Volume I, AFM 85-12 for adjustment of drives and speed reducers.

--- Make a followup check of heat distribution within the next day or two after starting up. If any rooms are too warm, adjust the dampers that serve them.

--- If any rooms are too cold, proceed as follows:

    --- Open the damper serving the cold rooms until the desired temperature is obtained.

    --- If the desired temperature is not reached with the dampers fully open, start closing the dampers that serve all other rooms. Closing these dampers will cause more air to go to the under-heated room and thus increase its temperature.

    --- Continue closing the dampers until the desired temperature is reached. One or more followup checks and adjustments, using the outlined "trial and error" method, may be required before the system is balanced.

--- Connect all heating outlets to the system according to manufacturer's instructions.

## Types of Warm Air Heating Systems

The principle used for the forced and gravity warm air heating system is the same. Both systems require a central heating unit for furnace, warm air ducts, cold-air returns and registers. The main difference between the two heating systems is the method of circulating the air.

## Gravity

The gravity warm-air system (figure 4-5) is one of the oldest and simplest. The furnace, essentially, is just a small metal box inside of a big one, with a sealed flue pipe heading from the inner box out through the bigger one to the chimney. Build a fire in the little box and you heat the air in the space between it and the bigger box that surrounds it. The heated air rises to the top of the big box end, enters a tip-top chamber, called a "plenum chamber or bonnet" to which hot-air ducts are connected. These big, up-sloping pipes carry the rising hot air to the room in the house above. The hot air floats up through the registers in the rooms, heats the rooms, and settles to the floor as it cools and becomes heavier. Once at floor level, it flows down through another set of ducts that carry it back into the bottom of the furnace. There, it picks up new heat and rises to the room again. The cycle continues as long as there's a fire in the furnace and the fire may be fueled by coal, oil or gas.

There are no moving parts in the circulating system so it works in silence, but it has some drawbacks. Because the difference in the weight per cubic foot of hot and cool air is only a tiny fraction of an ounce, the ducted air doesn't move with much force, so it can't push its way through a conventional dust filter without slowing down too much for efficient heating. Hence, gravity warm-air systems are usually unfiltered.

The gentle flow also makes it necessary to keep the warm-air ducts short to avoid too great a heat loss along the way. So the warm air registers are usually at the inside walls of the rooms closest to the furnace situated in the center of the basement And the return air registers are at the outside walls. They have to be on the opposite side of the room in order to draw the warm-air flow across. Thus, the hot air floats past the warmer inner walls first. Then, as it cools, it descends past the colder, outside walls and windows and enters the return registers for its downward glide to the furnace again. As a result, you may find the outside areas of some rooms a little chilly on very cold nights. Also, the easy, natural air flow may make the unit a bit slow to respond to the thermostat.

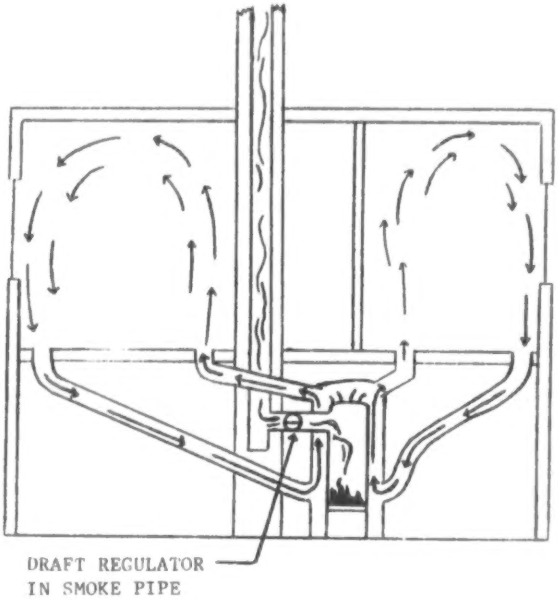


Figure 4-5. Gravity Warm-Air System

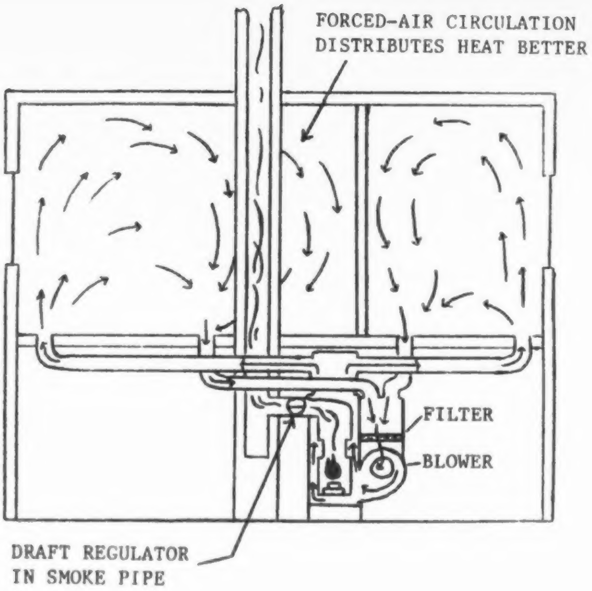

FORCED-AIR CIRCULATION DISTRIBUTES HEAT BETTER
FILTER
BLOWER
DRAFT REGULATOR IN SMOKE PIPE

Figure 4-6. Forced-Air System

Forced

Forced warm air (figure 4-6), one of the most popular modern systems, is very similar to the old gravity type. The main difference is that the forced system uses a centrifugal fan or blower (forced convection) instead of natural convection to attain positive air circulation. Figure 4-6 illustrates a typical forced-air system. The high velocity air stream carries the heat away from the hot furnace surfaces and into the rooms much more rapidly. So you can get much more heat from the same size furnace, or just as much heat from a smaller furnace. And, as the forced air stream can travel in any direction, you can take the furnace out of the cellar and put it anywhere you please--including the attic. The power-driven blower will shoot the heating air down, up, sideways, anywhere you want it.

The forced system also responds quickly to a thermostat allowing flexible heat delivery, so that widely varying demands of changeable weather are met with a minimum of over-heating.

## Types of Warm Air Distribution Systems

Satisfactory heating from warm air systems is absolutely dependent upon the proper distribution of warm air from the furnace to all portions of the space served. Warm air must be distributed in the quantities required to offset the rate of heat loss of each heated space, or temperature differences between rooms will occur. This differs somewhat from radiator systems where the size of the radiator is the most important factor in determining the rate of heat released to each room. With radiator systems, distribution is primarily a problem of getting enough hot water or steam to each radiator to be sure that the radiator heats to its rated capacity. It is not possible to deliver more heat through steam or hot water than the radiator is designed to transmit.

With warm air systems, however, the amount of heat reaching each room is determined by the rate of air delivery to that room so that temperature balance is entirely a problem of control of air distribution. In addition, the natural tendency of warm air to rise and cold air to fall within the heated space must be recognized. Air supply and return openings should be located with a view to eliminating air stratification and cold floors. In general, warm air registers should be located so as to deliver air to or along the areas of greatest heat loss and return grilles should be located where they will pick up cold air before it can spread to cause objectionable drafts.

There are various types of air distribution systems to satisfy differing requirements. The ones we are going to study are: perimeter systems (these include loop, radial and crawl space systems), extended plenum system, inside wall delivery systems and ceiling delivery systems.

Perimeter Systems

These systems use supply openings around the outside wall areas, near the source of the greatest heat loss. They are equipped with registers designed to "blanket" the cold area. This type of location delivers the warm air so that it mixes with the cool air from the heat loss area and infiltration points, and prevents or reduces draft.

The air returns to the furnace through centrally located, high sidewall, or ceiling registers; the return ducts may be located in the attic or other unheated spaces. Be sure the duct size is adequate for its load since in the normal design only about one-fourth of the total pressure at furnace outlet is available for return-air circulation. (That means 0.05 inch of water for a total pressure of 0.20 inch, when 0.15 inch of water is used on the supply side.) Return-air can be taken from crawl spaces where the furnace is located. In perimeter system installations, a down-flow furnace is normally used. In these furnaces, cold air enters the unit from above and discharges as hot air from the bottom or lower part of the furnace casing. All perimeter distribution systems are similar in performance but differ in design. The design selected depends on building conditions. Examples are the loop, the radial, and the crawl space systems.

PERIMETER LOOP SYSTEM. The loop system shown in figure 4-7 is one type of a perimeter system. It is used where concrete slab floors are placed directly on the

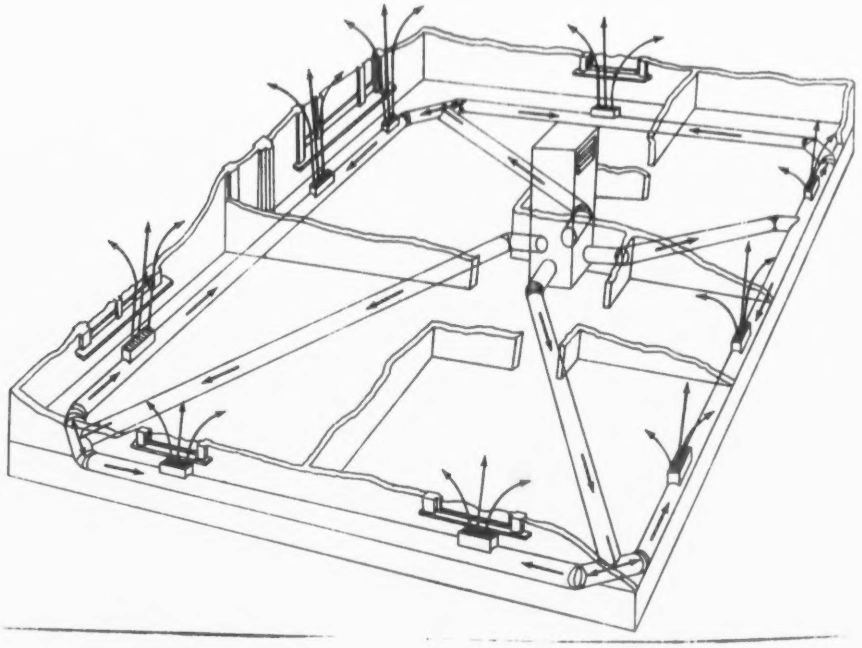


Figure 4-7. Perimeter Loop

ground. A warm air duct, with diffusers and grilles, extends completely around the perimeter of the building in a continuous loop which is supplied by radial feeder ducts from the plenum chamber. The ducts, buried in the slab, serve two purposes: they distribute warm air to the loop, and conduct heat which warms the floors. As in the other systems, warm air registers are located and designed to prevent the airstream from discharging against people at rest. No more than three diffusers should be placed in a section of loop duct between any two feeders.

PERIMETER RADIAL SYSTEM. Figure 4-8 illustrates a perimeter radial system. This air distribution system consists of individual ducts which run spokewise to each register from the plenum chamber of a more or less centrally located furnace. Normally, diffusers spread air uniformly over the register face. To reduce air velocity through the register, use registers with areas larger than the connecting ducts. Ducts can be run beneath the floor of structures with basement or crawl space, or embedded in concrete slabs if the building has no basement.

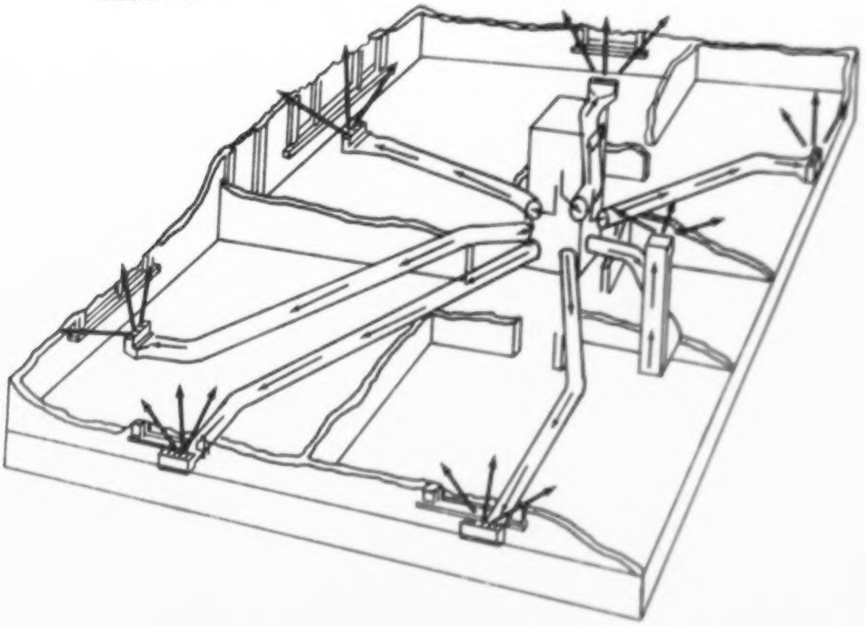


Figure 4-8. Perimeter Radial System

CRAWL SPACE PERIMETER SYSTEM. If a structure is built over a crawl space, the entire space can be used as a warm-air supply plenum. Warm air enters the room through perimeter flow registers located preferably beneath the windows: additional heat is supplied by conduction from the warmed floors. This system is not recommended for Air Force use.

### Extended Plenum System

The extended system (figure 4-9) is another popular arrangement. A very large rectangular duct (almost as large as the plenum) extends in a straight line from the plenum. Ducts branch off from the extended plenum to the wall registers. This heat distribution method comes in handy where the basement is to be finished for use as living space. The big advantage of the extended plenum system is the reduced resistance to the flow of air over a long run.

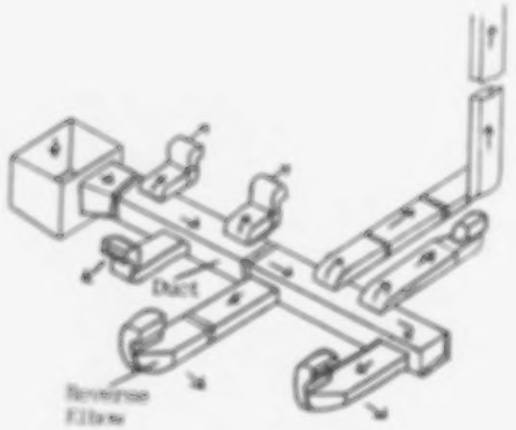


Figure 4-9. Extended Plenum System

### Inside-Wall Delivery System

Warm air perimeter heating is a relatively new concept. Older systems used different register locations to introduce the air into the heated spaces. One of these methods located the registers on an inside (warm) wall with supply openings either high on the side wall, or near the floor, and return openings near the greatest outside exposure. High sidewall registers should deliver the air horizontally or slightly downward so that it does not strike the ceiling or wall. The air velocity at the end of the throw should be around 50 feet per minute; the throw, about 75 percent of the distance that the airstream travels after leaving the diffuser before its velocity drops to 50 feet per minute.) For best results, use directional flow diffusers, which spread the air flow evenly over the register face. To reduce the outlet air velocity, use registers with an area larger than the connecting duct. Location of the warm air return grille depends on the situation of supply outlets. Baseboard returns are preferable to floor grilles.

### Ceiling Delivery System

This system (figure 4-10) is a modified extended plenum that uses ceiling diffusers to deliver the warm air to the heated space. With angular ceiling diffusers, the air stream is spread 360° and the rate of diffusion is high; however, the throw is rather low. Because of the short length of throw, high initial air velocities are often used.

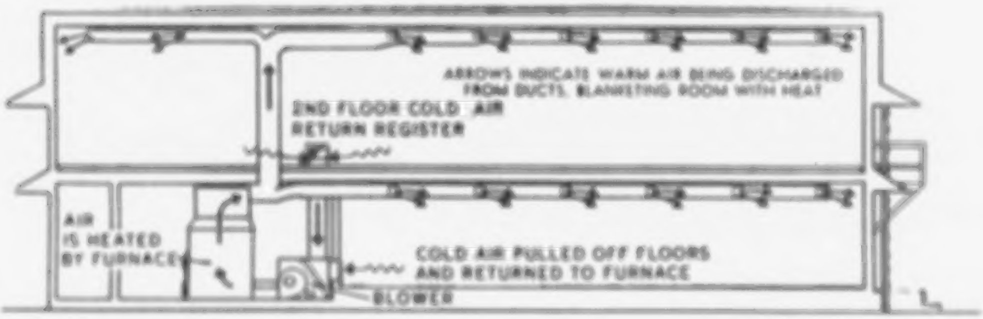

ARROWS INDICATE WARM AIR BEING DISCHARGED FROM DUCTS, BLANKETING ROOM WITH HEAT
2ND FLOOR COLD AIR RETURN REGISTER
AIR IS HEATED BY FURNACE
COLD AIR PULLED OFF FLOORS AND RETURNED TO FURNACE
BLOWER

Figure 4-10. Duct Layout in a Two-Story Barrack

## Construction Features

The first item needed for a warm air system is the furnace; it supplies the heating source for the system. The different types and components of furnaces were previously discussed.

The next item needed is a holding area for the warm air, after it has been discharged from the furnace. This is called the plenum chamber or bonnet. It mounts directly to the furnace's warm air outlet. It can be located on the top or bottom of the furnace, depending on the type of furnace used.

Next comes the warm-air and cold-air return ducts. The horizontal run ducts are called leaders and the vertical run ducts called risers. These ducts carry the warm air to the different parts of your house or building, and must be properly sized and located to carry the required amount of warm air to heat the building. The sizing and location of the warm air ducts will be determined by the engineering blueprints. All warm air heating systems must have a way for cold air to get back to the furnace. This can be accomplished in several ways:

--- By the use of cold-air return ducts.

--- By the use of registers located in the lower wall or on the floor.

--- By locating large louvers in the exterior walls of your furnace room.

## Inspecting and Cleaning Heating Ducts

Ducts are used to distribute air to conditioned rooms or spaces, and to remove or exhaust air from rooms. Heat ducts are usually constructed from sheets of aluminum or galvanized steel. Ducts may be either round or rectangular in cross section. Straight sections of round duct are usually formed from sheets rolled to the proper radius and assembled with a longitudinal grooved seam. Each end of a round section is swaged and assembled with the larger end of the adjoining section butting against the swage. The sections are held together by rivets, sheet metal screws, or by soldering. Rectangular ducts are generally constructed by breaking the corners and grooving the longitudinal seam.

Construct duct systems to avoid abrupt changes in size and direction and other resistance conditions which create noise and reduce air volume. Use interior vanes at elbows, and streamline obstructions.

The interior of ducts may be lined with sound-absorbing material to reduce noise caused by air passing through the ducts. It is usually more convenient to line all four sides of the duct interior, but a lining on one side over a longer length of the duct will, in general, give the same effect for the same area of applied sound-absorbing material. The exterior of ducts that carry conditioned air may be covered with an insulating material to prevent heat transfer between the ducts and the surrounding air.

Ducts should be constructed to enable them to be maintained easily. Provide access doors in the ducts to facilitate easy cleaning and inspection.

Inspect ducts annually for the following conditions: deformation; leakage losses caused by loose clean-out doors, broken joints, holes worn in ducts (most frequently in elbows), and poor connections to fans; and accumulations of material, such as dirt, lint and condensation of oil or water vapor, on the interior of the ducts. Repair or replace defective ducts or duct connections. Remove accumulations of foreign matter on the interior of the ducts by washing or vacuum cleaning. If applicable, inspect sound-absorbing and insulating material on the interior of the ducts to determine that the materials are installed securely and adequately. Inspect duty hangers and supports to insure that the ducts are supported substantially.

All heating outlets should be connected to the system according to manufacturer's instruction.

### Inspecting and Adjusting Distribution Dampers and Linkages

Warm air ducts for forced warm air heating systems are equipped with dampers and registers to control the flow of warm air. Figure 4-11 shows a diagram of a volume damper and splitter dampers.

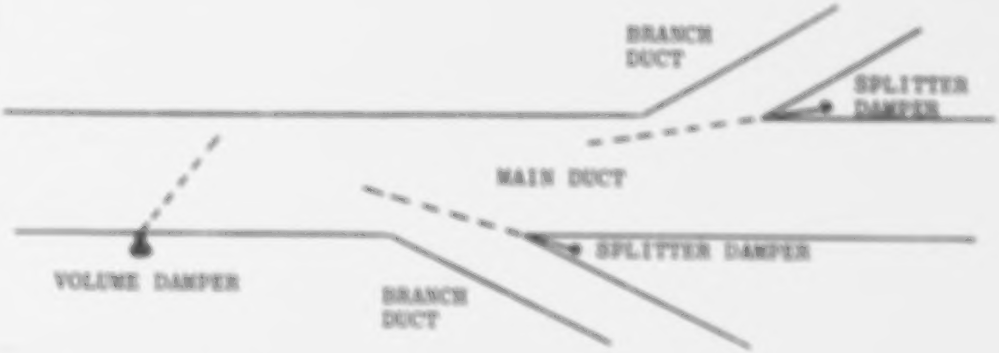


Figure 4-11. Volume and Splitter Dampers

Whenever the damper handle is bent or the damper shaft is twisted, it is difficult to determine the position of the damper, since the damper cannot be seen. In such a case, the damper can be positioned so as to shut off the flow of air to one of the ducts. During maintenance services, such dampers should be checked for alignment. All dampers should be equipped with a locking device and some means to indicate their true position.

After the dampers are checked for proper operation and true alignment and the system is in full operation, balance the system by adjusting the dampers in the main ducts and branch ducts.

## Removing and Cleaning Filters

Air filters are used to remove atmospheric dust from the incoming cool air. They are usually installed in return-air chambers, before the blower (as shown in figure 4-12). For the best results, never expose air filters to temperatures above 150°F. Refer to AFM 85-18, Maintenance and Operation of Refrigeration, Air Conditioning Evaporative Cooling and Mechanical Ventilating Systems, for a description of the types of air filters.

### Air Filter Performance Factors

Three main factors determine the performance of air filters: face velocity, resistance to airflow, and filter efficiency.

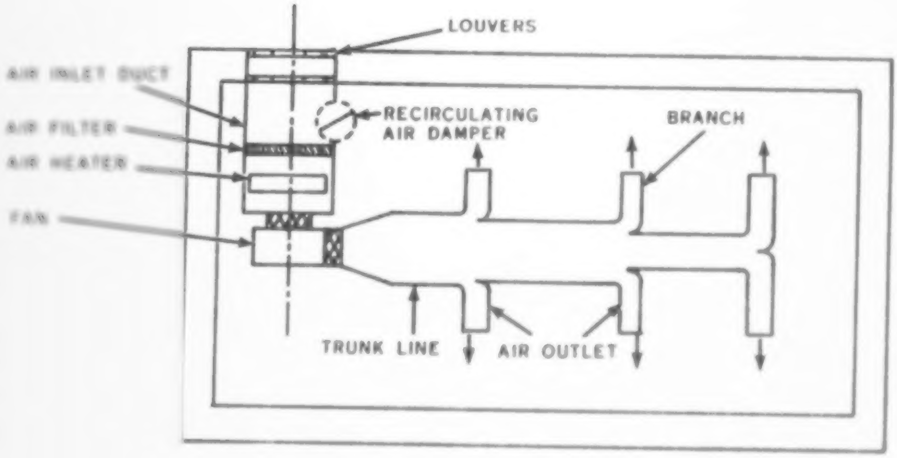


Figure 4-12. Central Fan System of Heating

FACE VELOCITY. The average velocity of air entering the effective face area of the filter is called the face velocity. The effective face area is the total area within the filter frame, including any that is occupied by bracing or grid members.

RESISTANCE TO AIRFLOW. The resistance of a filter to airflow is usually measured as the pressure drop caused by the filter, expressed in inches of water (1 inch of water equals 0.03613 psi). The pressure drop of a given filter depends on its cleanliness and the volume of airflow. As airflow increases or the filter becomes loaded with dust, the pressure-drop through the filter increases. Filter resistance increases rapidly as dust accumulates and may cause a substantial reduction in airflow. Rate filters, when they are clean and operating at design airflow, in inches of water (pressure drop).

FILTER EFFICIENCY. The measure of an air filter's efficiency is its capacity to remove dust from the entering air.

### Types of Filters and Their Maintenance Procedures

When air filters are used, they must be inspected at least once each month and cleaned or replaced whenever necessary. Dirty filters reduce airflow, or impair heating performance, and increase fuel consumption.

THROW AWAY. The condition of throw-away filters can be roughly checked by holding them up to the light. When little or no light shines through the filter, a replacement is required. Washing and recoating of these filters is not recommended. They are usually made with a graduated filtering medium most densely packed on the outlet side, the purpose being to increase the dirt holding capacity of the filter. When installing this type of filter, make certain that the filter is placed with the denser filtering medium on the outlet side. These filters are usually marked to indicate the proper direction of airflow through them.

CLEANABLE. Cleanable filters can be renewed by washing them in a strong solvent and allowing them to dry thoroughly, as shown in figure 4-13. They should then be recoated by a hand sprayer. Filters are recoated only with an adhesive specified for this purpose. These adhesives, which are available through filter manufacturers, should be odorless and fire resistant. They should have a high capillarity, or ability to wet, hold dust at all operating temperatures, prevent mold formation, and evaporate slowly.

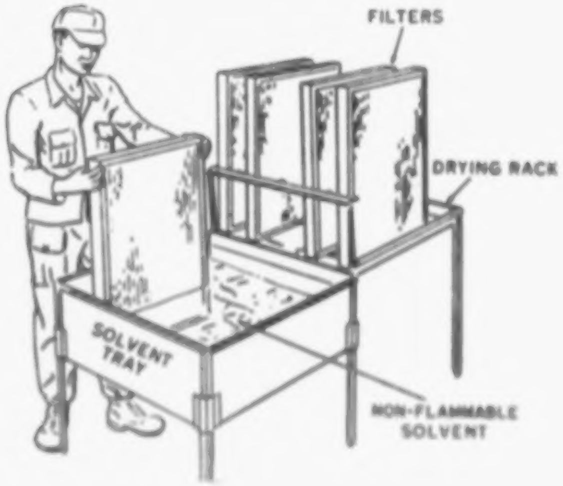


Figure 4-13. Washing and Drying Cleanable Filters

### Blower Maintenance

All motors are mounted on adjustable bases to permit adjustment of the blower belt tension. Unless a manufacturer specifically recommends a tighter adjustment for this purpose, adjust the base of the motor so that there is from 1-1/2 to 2-1/2 inches of play in the best as illustrated in figure 4-14. Make certain that both pulley wheels are in perfect alignment.

In actual operation, an electric motor turns the blower by means of a V-belt. As the blower turns, cool air flows through the filters which remove the dust and dirt. From the filters, air flows into the fan which forces it past the firebox to the heat exchanger of the furnace where it is heated. The heated air is then forced into the warm air ducts into the various rooms. As more air is forced into the rooms, the cold air in the rooms flows back to the furnace through the cold air returns to start another cycle.

Most warm air circulating blower units are built as part of the furnace by the manufacturer. However, if the blower unit must be mounted separately, care should be taken to fasten the blower and blower motor on a masonry base, in true alignment. The base should be at least three inches thick and extend at least 12 inches beyond the furnace casing. Install filters on the inlet side of the casing so all air will be filtered before entering fan.

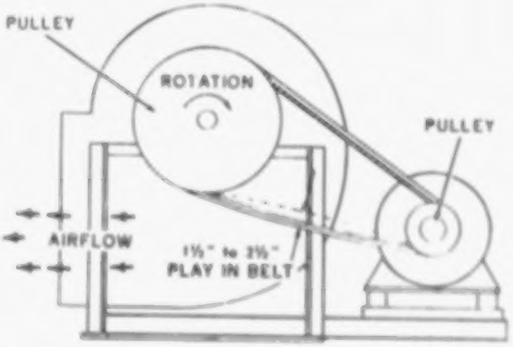


Figure 4-14. Blower Fan Belt Adjustment

The cabinet, housing the blower unit, should be fabricated with doors to facilitate oiling, adjustment and minor repairs on the motor and blower. Doors should also be provided to enable the replacement of air filters. The complete unit should be reasonably well constructed to prevent air leakage.

Seal all blower casing joints with asbestos tape or caulking compound. Check the grouting around the base of the blower casing and furnace and make repairs if necessary.

The blower and electric motor bearings require regular oiling at least twice each heating season. These bearings are usually fitted with oil cups. The proper oil recommended by the manufacturer should be used. Care should be taken not to over oil the bearing. However, the bearing should be oiled sufficiently, otherwise the shaft will seize to the bearing, causing the motor and blower to stop.

## SUMMARY

The Air Force uses warm air heating systems to a great extent at its bases. The forced warm air systems have a decided preference over the gravity warm air systems. The heating supervision should procure manufacturer's manuals for each of these systems. A thorough study of these manuals will enable heating personnel to operate and maintain these systems more efficiently.

## QUESTIONS

1. What are the two types of warm air heating systems used for the heating of residential and small industrial buildings?

2 How should warm air ducts be cleaned?

3. Why should dampers be equipped with a locking device?

4. Why is true alignment necessary for the installation of a blower and blower motor?

5. How are the permanent type filters cleaned?

6. How does a forced warm air heating system differ from a gravity warm air heating system?

7. What types of furnaces are used with the gravity warm air heating system?

8. Why are asbestos boards on a wooden wall next to a furnace?

REFERENCE

AFM 85-12, Volume II, Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization

# SOLID FUEL BURNERS

## OBJECTIVE

To help you learn about the characteristics of coal, the different types of coal, how coal is stored and coal stokers.

## INTRODUCTION

Although coal requires much more equipment to be burned than gas or oil its relatively low cost offsets the necessity for this extra equipment.

Before coal can be burned it must be handled quite a few times. After it leaves the mines it arrives at coal storage areas where the coal is checked and stockpiled. From there it is taken by truck to the individual heating plants where it again is handled quite a few more times before it reaches the heating unit.

This study guide will provide you specific information about coal including:

--- Definition of Coal

--- Characteristics of Coal

--- Coal Storage Area

--- Inspecting and Collecting Coal Samples

--- Coal Burning Equipment

## INFORMATION

### Coal Defined

Coal is a mineral originated from decayed trees, ferns, and other types of vegetation. It is composed of varying proportions of carbon, hydrogen, oxygen, nitrogen, sulfur, and several noncombustible materials which make up the ash. The ash is composed mainly of silica, alumina, iron, lime, and small quantities of magnesia.

### Characteristics of Coal

A brief description of the more common coals used by the USAF is given in the following paragraphs, but it should be recognized that there are no distinct lines of demarcation between the kinds and that they graduate into each other.

ANTHRACITE. Anthracite is clean, dense, hard coal which creates little dust in handling. It is composed almost entirely of fixed carbons. It is comparatively hard to ignite, but burns freely when well started. It is non-caking, burns uniformly and is smokeless with a short blue flame. This type coal requires little attention to the fuel-bed between firings. The average BTU content of anthracite coal is 14,440 BTUs per pound.

LOW-VOLATILE BITUMINOUS. Semi-bituminous coal is soft and friable (easily crumbled). Fines and dust are created by handling it. It ignites somewhat slowly and burns with a medium length of flame. Its caking properties increase as the volatile matter content increases, but the coke formed is relatively weak. Having only half the volatile matter as bituminous coals, it can be burned with less production of smoke and is sometimes called a smokeless coal. The average BTU content for semi-bituminous coal is 15,480 BTUs per pound.

BITUMINOUS COAL. Bituminous coal is a classification covering a large range of coals including many types having distinctly different composition, properties and burning characteristics. These coals range from the high-grade bituminous coals of the East to the poorer grade coals of the West. Their caking properties range from coals which melt completely to those from which the volatiles and tars are distilled without change of form so that they are classed as non-caking or free-burning. Most bituminous coals are strong and non-friable enough to permit the screened sizes being delivered free from fines. In general, they ignite easily and burn freely. The length of the flame varies with the different coals, but it is long. Much smoke and soot are possible, if improperly fired, especially at low rates of burning. The average BTU content for bituminous coal is 13,880 BTUs per pound.

SUB-BITUMINOUS COAL. Sub-bituminous coals occur in the wetern states. They are high in moisture content when mined and tend to break up as they dry, or when exposed to the weather. They are liable to ignite spontaneously when piled or stored. They ignite easily and quickly; have a medium length flamep; are non-caking and free burning. The lumps tend to break into small pieces when poked, and very little smoke or soot is formed. The average BTU content of lignite coal is 7,400 BTUs per pound.

MOISTURE. All coal contains some natural moisture (range from 1 to 5 percent in eastern coals and over 40 percent in some Texas lignites). This inherent moisture lies in the pores of the coal and forms a true part of it, being retained when the coal is air dried. Surface moisture depends on conditions in the mine, on length of time in transit, and on weather conditions.

A moisture determination involves heating a specially prepared sample in a preheated oven (at 220-230°F) for one hour. Loss of weight divided by original weight gives percent moisture.

Moisture must be transported, handled and stored; its presence in large amounts increases the difficulty and cost of these operations. Looked at another way, moisture replaces an equal amount of combustible material and thus decreases the heat content per pound. In addition, some of the heat liberated in the furnace goes to evaporating the moisture in the fuel.

ASH. Ash is the incombustible mineral water left behind when coal burns completely. It differs from "ashes" as the plant operator knows them, because ashes taken from a furnace always contain some unburned coal. Laboratory determination of ash involves heating dried coal (after the moisture determination) until red hot; then continue heating at about 1300°F until a constant weight is obtained. Weight of the remainder, divided by weight of the original sample weight, gives the percentage of ash content.

Like moisture, ash is an impurity which increases shipping and handling cost. It must be removed from the furnace and the plant, requiring additional equipment and expense in most cases. Ash constitutes the biggest single factor in fuel-bed and furnace problems, such as clinkering and slagging.

SULFUR. Sulfur is an undesirable element in coal for heating plant use. It plays a part in clinkering and slagging, in corrosion of air heaters, economizers, breechings and stacks, and in spontaneous combustion of stored coal. The determination of sulfur content in coal is a laboratory process and is not the responsibility of the heating specialist or technician.

ASH-FUSION TEMPERATURE. Ash-fusion temperature is measured by heating cones of ash in a gas furnace. The temperature at which the cone fuses down to a round lump is called the softening or ash-fusion temperature. Ash-fusion temperature serves as the best single indicator of clinkering and slagging tendencies under given fuel-bed and furnace conditions.

HEATING VALUE. The heating value of coal is measured by burning a sample of a "bomb" calorimeter. Filling the bomb with oxygen under pressure insures a complete combustion. The value found by this test is the higher heating value, or gross calorific value. All fuels containing hydrogen have another heating value called the lower or net calorific value. The difference arises because hydrogen burns to form water vapor. Normally, the higher heating value or gross calorific value of a fuel is specified.

CAKING AND COKING COALS. Considerable confusion exists regarding the proper use of the terms caking and coking. Heating coal drives off the volatile matter leaving behind practically pure carbon: this is called coke. It may take the form of small powdery particles or may fuse into lumps of varying sizes and strengths. Formations of coke, in one shape or another, represents an intermediate stage of combustion in any fuel bed; the difference lies in whether or not a plastic stage occurs and lumps of coal form. Coal which becomes plastic and forms lumps or masses of coke are called caking coals, while those which show little or no fusing action are called non-caking or free-burning coal.

VOLATILE MATTER AND FIXED CARBONS. In a way not yet clearly known, coal holds combustible gases such as hydrogen, methane and other hydrocarbons, and incombustible gases such as carbon dioxide and nitrogen. This is a volatile matter. Heat releases these gases, leaving behind a solid fuel, consisting principally of carbon, but containing some hydrogen, oxygen, sulfur and nitrogen not driven off with the gases. This is called fixed carbon. Volatile matter is measured by heating a sample at approximately 1750°F for exactly seven (7) minutes. The loss of weight, minus the moisture, divided by the original sample weight, gives the percentage of volatile matter. Subtracting the percentage of moisutre, ash and volatile matter from 100 percent, yields the percentage called fixed carbon.

## COAL STORAGE

The Air Force stores coal to have available at all times a reasonable supply of the proper kinds, sizes, and grades of coal in accordance with the requirements of the installation equipment, and to provide an emergency supply for use in case of interruption of the normal delivery schedule.

The amount of the annual coal requirement that should be stored at a given installation may vary somewhat according to size of plant, normal transportation facilities from coalfields, ratio of summer demand to winter demands, type of coal, and coal yard conditions. The minimum reserve stockpile to guard against strikes and disaster consists of a 30-day supplye, based on the maximum coal burning month of the year, or 20 percent of the total fuel consumption for the year, whichever is greater.

## PROCEDURES FOR MAINTAINING A COAL STORAGE AREA

Coal should be stored on ground that has been properly graded and surfaced. A typical coal storage layout is shown in figure 5-1. Improper storage of coal may cuase spontaneous combustion. Usually, some coal is wasted when it is stored on soft ground because it sinks into the ground and mixes with dirt, gravel, clay, rock, etc. When a situation of this type occurs, the foreign particles of the coal usually warp the grates of heating units, to say nothing about the loss of manpower and wear and tear upon the equipment used to move such noncombustible materials. Heavy coal losses usually occur when coal is stored without proper drainage.

Coal should never be stored near sources of heat. Fresh coal should never be piled over old coal. Storage piles and storage surfaces should be kept free of metal scrap, rags, paper, waste, scrap wood, glass bottles, and other foreign materials. Some bituminous coal, including lump, egg, and nut, should not be piled higher than 18 feet except with the specific approval of the Air Force command concerned. Anthracite coal may be stored to any desired height within economic limits. Storage of bituminous, run-of-mine coal should be limited to a maximum height of 13 feet, unless higher stockpiling is approved by the Air Force command concerned.

Coal is generally stored in stockpiles 300 feet long and 36 feet wide. An allowance of 20 feet should be made between the stockpiles for firebreaks. The firebreaks also serve as driveways and loading zones. This arrangement permits efficient truck loading and travel, ample room to operate coal handling equipment, and sufficient room to spread or shift the coal in case a fire starts in one of the stockpiles. Shifting and rehandling of coal in stockpiles should be held to a minimum in order to prevent breakage and disintegration of coal into smaller pieces.

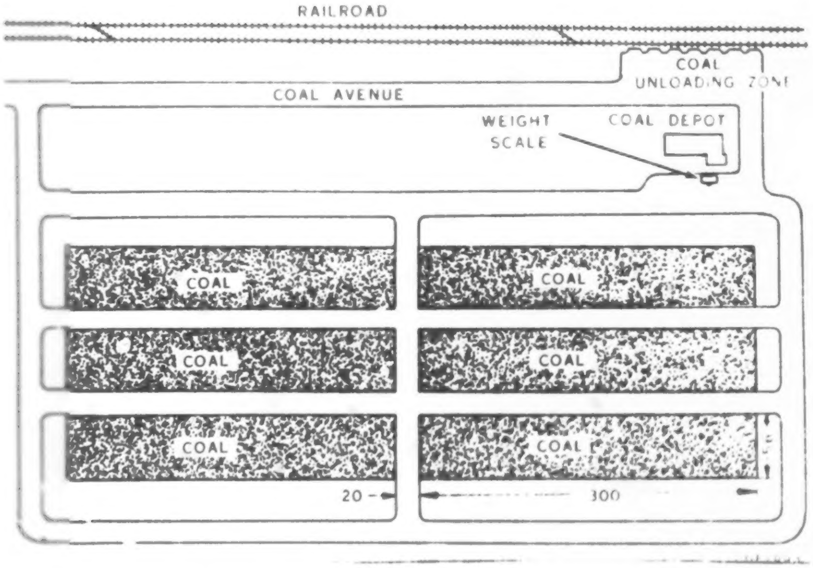


Figure 5-1. Coal Storage Layout

If is it necessary to move the coal it must be done with a clamshell crane (Figure 5-2). There will be little or no damage to the coal, providing the coal is not discharged until it is close enough to the pile so that only enough room is allowed to open it. Storage stockpiles of sized coal should never be shifted by pushing with a bulldozer.

Storage piles should be inspected at least once a week for evidence of excessive heating or spontaneous combustion. Such evidence is ordinarily discovered by steam or by an odor of coal gases escaping from the coal piles. For complete inspection of the coal piles, 3/4-inch metal pipes, closed at the bottom and reaching nearly to the base of the coal, are placed in the coal pile approximately every 5 feet. In this manner, thermometers may then be lowered into these pipes to check the temperature of the coal pile at that point. The pipe should not be removed once it has been inserted because the hole left in the pile by the pipe aids in the generation of heat. If the temperature of the coal reaches 120°F, the coal should be watched closely for any rapid rise in temperature; and plans should be made for immediate removal of the hotspot. However, if the temperature rises slowly to about 160°F within a week, there is a danger of spontaneous ignition; and preparation should be made to remove the hotspot immediately.

Water should not be applied to burning storage coal piles to extinguish a fire or to storage coal piles which are heating. Water has a tendency to aggravate the condition and spread the fire to other points of the storage pile.

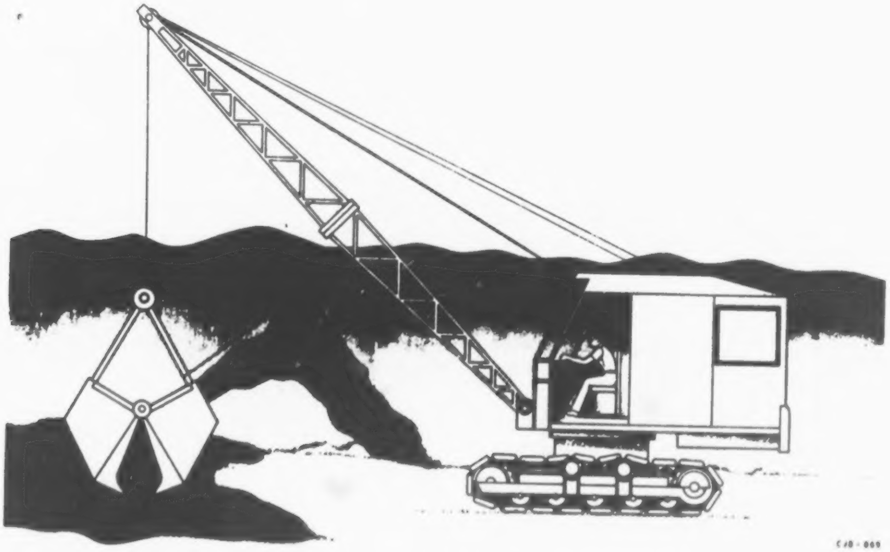


Figure 5-2. Clamshell Crane

## INSPECTION OF COAL SHIPMENTS

Coal inspection insures that the coal supplier complies with the coal contract specifications. It includes a visual inspection and a chemical analysis. A visual inspection is made to see if the shipment is made in the type of car specified in the contract. As stipulated on DD Form 416, Purchase Request for Coal, Coke or Briquetts, first and second preference must be stated in the space provided. If coal is shipped in an unauthorized type of railroad car, it should be accepted only under protest, through the appropriate Air Force command, to the purchasing agent.

When inspecting coal to determine that it is reasonably free from impurities, the inspector must rely on his knowledge of the appearance of previous shipments. The relative condition of any carload must be established by comparison with the average condition of previous carload shipments from the same source. When visually inspecting a carload or truckload of coal, you must examine closely the entire top of the car. Inspect it at nine or more points; in three diagonal lines across the top of the car, dig into the coal and expose it to a minimum depth of 2 feet.

Make sure the coal is free of slate, boney coal, sulphur balls, rocks, dirt, mud, clay, and other impurities. Coal that is stained or colored yellow, red, orange, or chalky gray is generally outcrop coal or coal with cover so shallow that surface water seeps into the stratum of coal and stains it not only on top but also on slips and butts. (A stratum is a sheetlike mass of sedimentary rock or earth of one kind, usually in a layer between beds of other kinds.) Oridinarily, outcrop coal is of poor quality, high in ash, low in heat units, and soft and friable (easily crumbled).

The loss or theft of coal in shipment should not exceed 1 percent of the weight of coal as it is shown on the shipping bill of lading. The loss of coal can be detected by the disturbed or irregular appearance of the coal at the top of the car. If the contents of the car appear to have been disturbed, a record of this is made on AF Form 97, Coal Receipt. Coal should be rejected when the results of the visual inspections are unsatisfactory. In this case, the civil engineering office of the appropriate command concerned should be notified immediately and the authority obtained for rejection.

## COLLECTING COAL SAMPLES

Sampling is one of the most important features of determining the successful and satisfactory application of the specification method of purchasing coal. Its purpose is (1) to furnish the means whereby the Government is assured of receiving the coal contracted for; (2) to protect the interest of the Government by providing the means for determining liquidated damages if contractors fail to deliver coal of the quality guaranteed; and (3) to furnish the purchasing officer an official basis for making his purchases. The importance of proper sampling and analyzing in the Government coal purchases is therefore obvious.

Samples must be collected by a trained and experienced sampler. Officials responsible for the sampling must witness the process from time to time to insure proper collection and preparation of the samples. A sampler may be required to certify the method of collecting and preparing samples. The purpose of certification is to stress the importance of doing the sampling conscientiously and to fix the responsibility for proper sampling. Each Air Force command and base using coal is required to have personnel available who are trained and certified to sample coal.

A gross coal sample, totaling not less than 1000 pounds of coal, should be gathered in proportionate amounts from the total cars of coal to be examined. The gross sample must not represent more than 20 cars of 1000 tons, or include coal from mines other than that which is included in the contract. The weight of coal taken from individual cars to make a gross sample varies with the number of cars. For instance, if one car is sampled, then 1000 pounds should be taken from that car. However, if 20 cars are sampled, then 50 pounds should be taken from each car. The same procedure is used when taking samples from dump trucks, except that with dump trucks, the samples can be taken from more than 20 truckloads provided the total tonnage does not exceed 1000 tons.

## COAL BURNING EQUIPMENT

Coal may be fed into a heating unit by any one of several methods. It may be fed either by manual or by mechanical means. Feeding coal by mechanical means is by the use of mechanical coal stokers. A coal stoker feeds coal to a heating unit intermittently upon temperature or pressure demand, a special time or hold-fire control is used to maintain a fire during periods when heat is not required.

Stoker firing has many advantages over hand firing of coal. Stoker firing permits the use of cheaper grades of coal, maintains a more even temperature, increases the efficiency of combustion, reduces labor requirements, and increases the capacity of the heating units.

Mechanical coal stokers are classified according to their coal feeding rates. The following classification of mechanical stokers has been made by the United States Department of Commerce, in cooperation with the Stokers Manufacturer's Association.

Class 1. Burning capacity of under 61 pounds of coal per hour.

Class 2. Burning capacity of 61 to 100 pounds of coal per hour.

Class 3. Burning capacity of 100 to 300 pounds of coal per hour.

Class 4. Burning capacity of 300 to 1200 pounds of coal per hour.

Class 5. Burning capacity of 1200 pounds of coal per hour or over.

Stokers also may be divided into various types, such as the underfeed, spreading, traveling or chain grate, and overfeed. Each type has its own field of application, depending primarily upon the characteristics of fuel used. The choice of the proper stoker also depends upon several other factors, such as the capacity of the heating unit, amount of ash in the fuel, shrinking characteristics of the fuel, amont of draft available and the size of the firebox. For this reason, stokers may vary in design as well as construction, but the rate of feeding coal determines their class.

In this study section, coal burning equipment will be covered in the following main topics:

--- Underfeed Stokers

--- Spreader

--- Traveling or Chain Grate

--- Overfeed Stokers

--- Pulverized Coal Burners

## Underfeed Stokers

In underfeed stokers, coal is force-fed into the base section of a retort. As the coal travels from the bottom of the retort, it enters the oxidizing zone and then the reducing zone. This vertical movement of the fuel usually provides a means for ash discharge. Underfeed stokers may be either the screw or the ram type.

The essential parts of an underfeed stoker are: hopper, feeding device, retort, tuyeres, grates, fan, drive and controls.

### Hopper

This is the container which holds the fuel that is to be fed into the retort. Its capacity depends on the type and capacity of the stoker. Some have agitators to prevent coal from arching; others depend on the slope of the sides (see figure 5-3).

### Feeding Device

This device can be either the screw or the ram type. The screw feed is generally used in small stokers, the ram is larger ones. The ram is a piston or plunger which injects the fuel by a reciprocating motion. It is connected to the driving mechanism by means of a connecting rod (see figure 5-3).

### Retort

The shape and size of retorts depend on the capacity of the stoker. Generally they are oblong in shape. On the top and side of the retort are individual iron segments (called tuyeres) with openings through which the primary air for combustion enters. The tuyeres are made in comparatively small sections to allow for expansion and to reduce stresses. Underfeed stokers may be of the single retort type or the multiple retort type. Multiple-retort stokers are always ram fed and are used on the larger boilers (see figure 5-3).

### Grates

The tuyere blocks which form the top of the retort are surrounded by dead plates (in smaller stokers) or by side and dumping grates. Usually the side grates are inclined to promote gravity movement of the burning coal to the ash discharge area. They can be stationary or moving. Sometimes they operate in a wave-like motion by means of an oscillating shaft to distribute the burning coal and help move it to the dumping grates. Dumping grates usually have openings which provide air to burn any remaining combustible material in the fuel. Ash disposal may be continuous (in stokers equipped with clinker grinders) or intermittent (in stokers equipped with dump plates) (see figure 5-4).

### Fan

Combustion air is generally supplied by multi-vane fans through a metal duct which discharges in a windbox surrounding the retorts. The windbox may be divided into zones to permit better control of the air supply to the fuel box. Secondary air must be provided above the fuel bed to burn the volatile matter and assure complete turbulence. See figure 5-3.

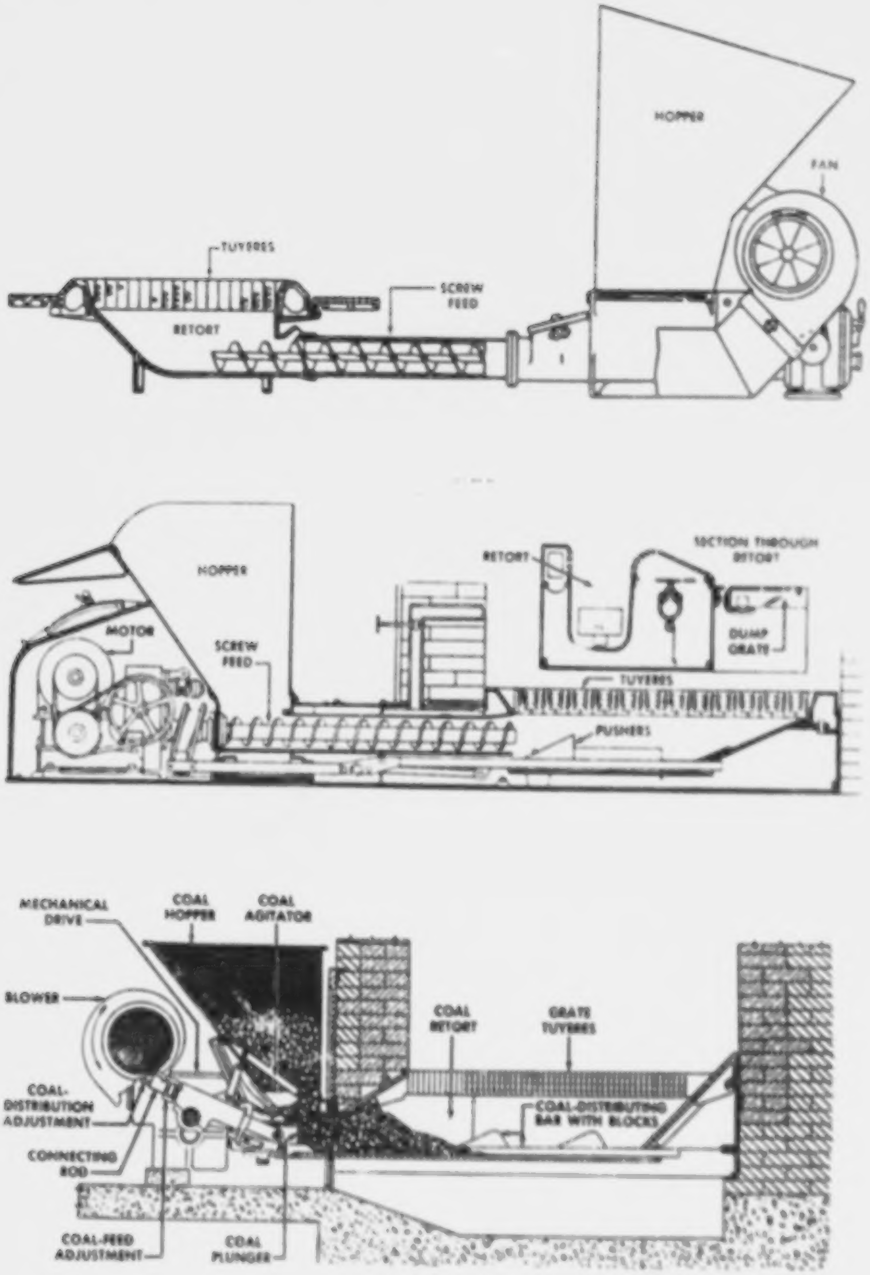

TUYERES
SCREW FEED
RETORT
HOPPER
FAN
HOPPER
MOTOR
SCREW FEED
RETORT
SECTION THROUGH RETORT
DUMP GRATE
TUYERES
PUSHERS
MECHANICAL DRIVE
COAL HOPPER
COAL AGITATOR
BLOWER
COAL RETORT
GRATE TUYERES
COAL-DISTRIBUTION ADJUSTMENT
COAL-DISTRIBUTING BAR WITH BLOCKS
CONNECTING ROD
COAL-FEED ADJUSTMENT
COAL PLUNGER

Figure 5-3. Screw Feed and Single Retort Stokers

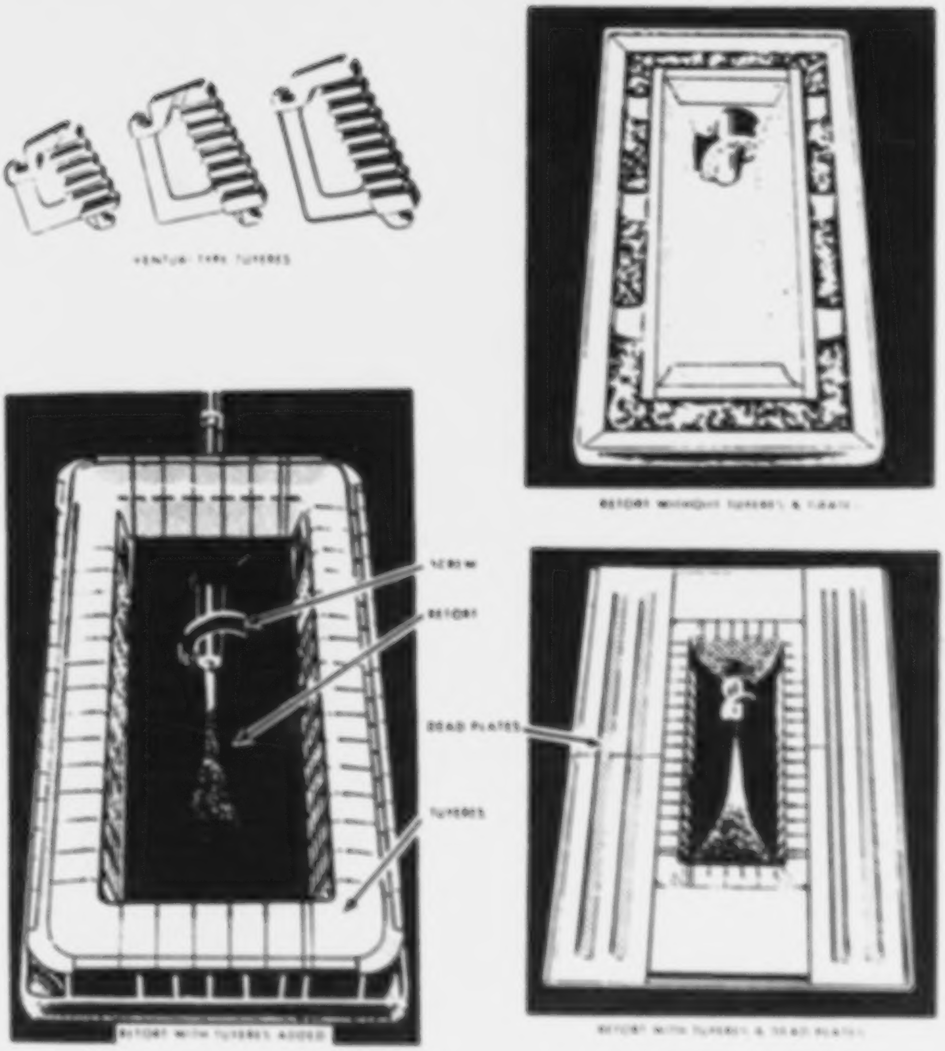

VENTURI TYPE TUYERES
RETORT WITHOUT TUYERES & GRATE
SCREW
RETORT
DEAD PLATES
TUYERES
RETORT WITH TUYERES ADDED
RETORT WITH TUYERES & DEAD PLATES

Figure 5-4. Screw-Feed Hopper Type Stoker with Stationary Grate

### Drive

Stokers are driven by electric motors, steam engines, and steam turbines. Some units use mechanical transmission for speed reduction and speed change; some use hydraulic transmission; others use variable speed V-belt drives (see figure 5-3).

### Controls

The heat output of the stoker depends on the amount of coal and air. The volume of air is regulated manually or automatically by fan inlet or discharge dampers or by a change of fan speed. The amount of coal fed depends on the speed of the drive by varying the length of stroke of the ram or by varying the frequency of the stroke.

## Spreader

Spreader stokers are usually of the pneumatic-feed or mechanical-feed design. Due to the limited application of the pneumatic type we will limit our discussion to mechanical spreader stokers.

In general, the mechanical spreader stoker consists essentially of a feeder, a spreading mechanism (usually in the form of a rotor provided with paddles or blades), a grate, and fans for primary and secondary air. Raw coal is delivered by the feeder to the spreader at a rate sufficient to generate the required amount of steam. The spreader throws the coal into the furnace where the finer particles burn in suspension. The coarser particles which form the fuel bed fall on the grate. There, the coal ignites at the surface and burns down through the fuel bed. A sufficient number of openings in the grate permit an even distribution of air. Stationary or dumping grates can be used to dispose of ash. Vibrating or oscillating grates are often employed in units in the 12,000 to 60,000 pounds-per-hour capacity range to provide for continuous ash discharge. Traveling grates or chain grates are generally used on the larger types. In these grates the direction of travel is usually from rear to front with a continuous ash discharge to a front ash pit.

Two of the more common mechanical spreader stokers are the underthrow rotary-feed and the overthrow reciprocating plate-feed.

### Underthrow Rotary-Feed Stokers

In this type of stoker (see figure 5-5) raw coal from the coal hopper is delivered by the rotary feeder to a circular tray. An underthrow rotor distributor picks it from the tray and throws it into the furnace. The distributor consists of four rows of blades twisted to provide uniform distribution of the coal in the furnace. The circular tray can be raised to compensate for wear of the rotor blades. It also can be moved parallel to the travel of the blade tip.

The speed of the rotary feeder determines the output of the stoker. The speed of the distributor and the position of the circular tray determine the distribution of the coal in the furnace. Air is supplied by a separately driven fan and is regulated by changing the fan's speed or adjusting its inlet or outlet dampers. The air is admitted under the grates.

### Overthrow Reciprocating Plate-Feed Stoker

In this stoker (see figures 5-6 and 5-7), a reciprocating feed plate pushes raw coal from the coal hopper to a spilling plate. From there, it is discharged to a rotor drum with blades (the spreading mechanism). The rotor throws the coal into the furnace and onto the fuel bed. The position of the spilling polate and speed of the rotor determine the disposition of coal along the length of the furnace. The length of travel and the frequency of the reciprocating feeder determines the rate of feed. Air is supplied in the same manner as for the underthrow feeder stoker.

## Traveling or Chain Grate

Traveling grate and chain grate stoker differ only in the construction of the grate.

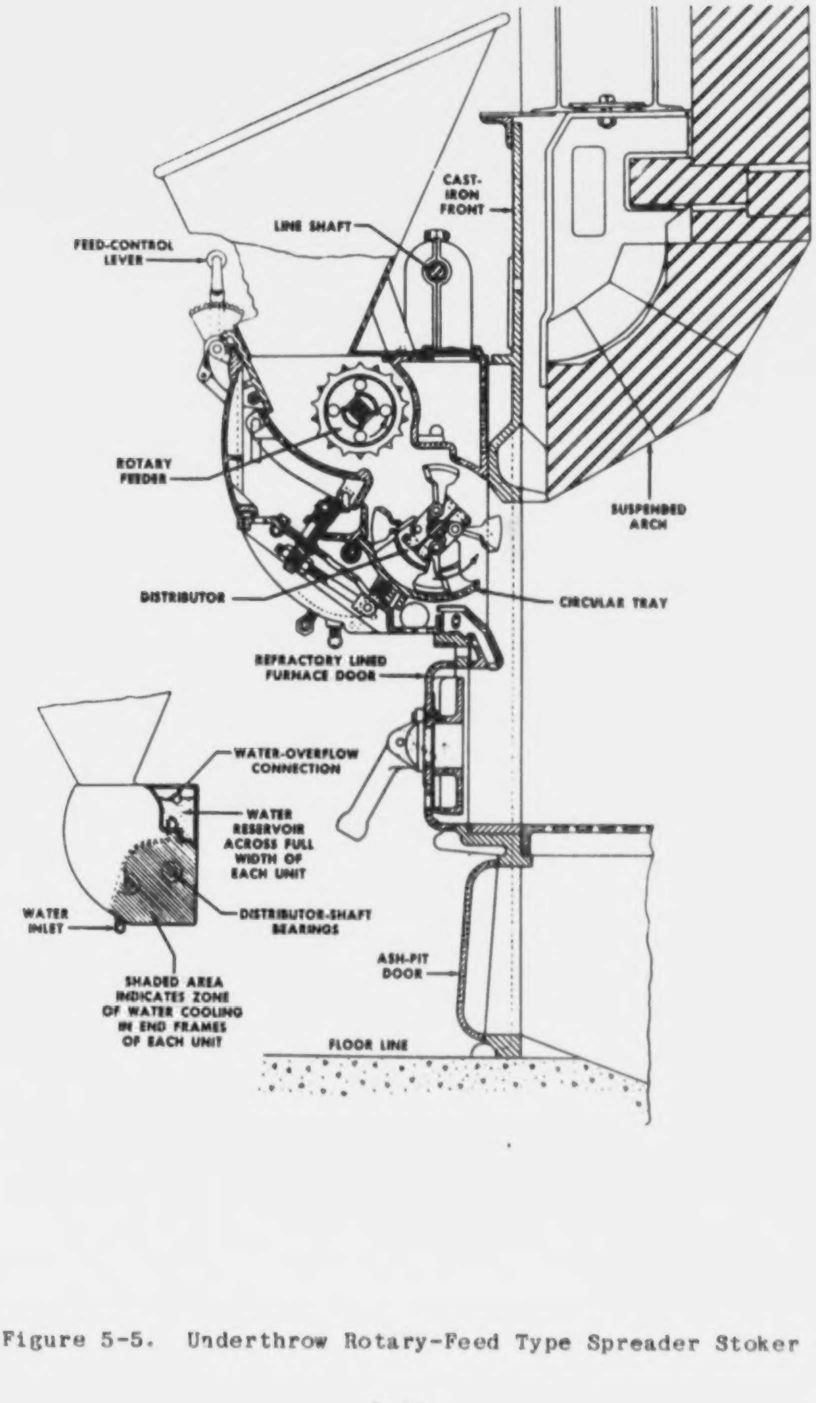

CAST-IRON FRONT
LINE SHAFT
FEED-CONTROL LEVER
ROTARY FEEDER
SUSPENDED ARCH
DISTRIBUTOR
CIRCULAR TRAY
REFRACTORY LINED FURNACE DOOR
WATER-OVERFLOW CONNECTION
WATER RESERVOIR ACROSS FULL WIDTH OF EACH UNIT
DISTRIBUTOR-SHAFT BEARINGS
WATER INLET
SHADED AREA INDICATES ZONE OF WATER COOLING IN END FRAMES OF EACH UNIT
ASH-PIT DOOR
FLOOR LINE

Figure 5-5. Underthrow Rotary-Feed Type Spreader Stoker

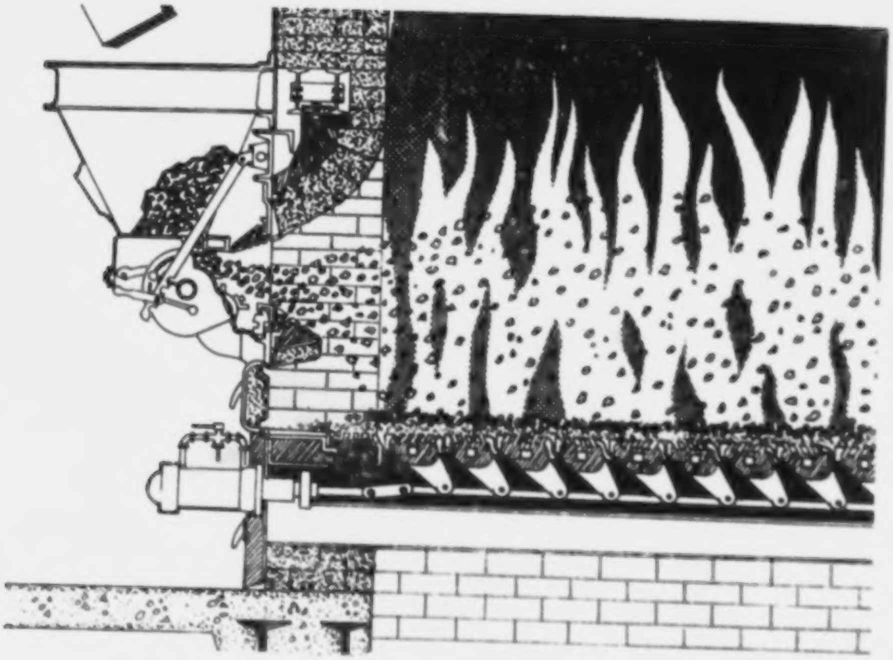


Figure 5-6. Overthrow Reciprocating Plate-Feed Type Spreader Stoker

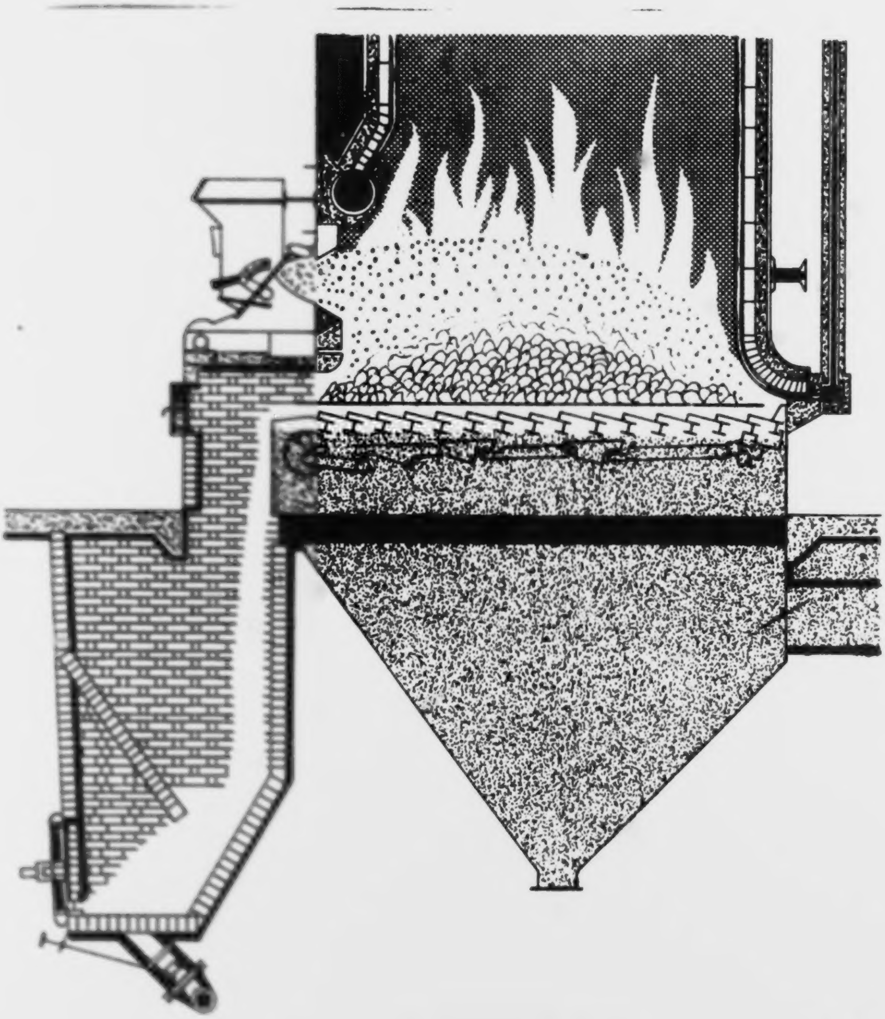


Figure 5-7. Continuous Ash-Discharge Grate with Overthrow Coal Feeder

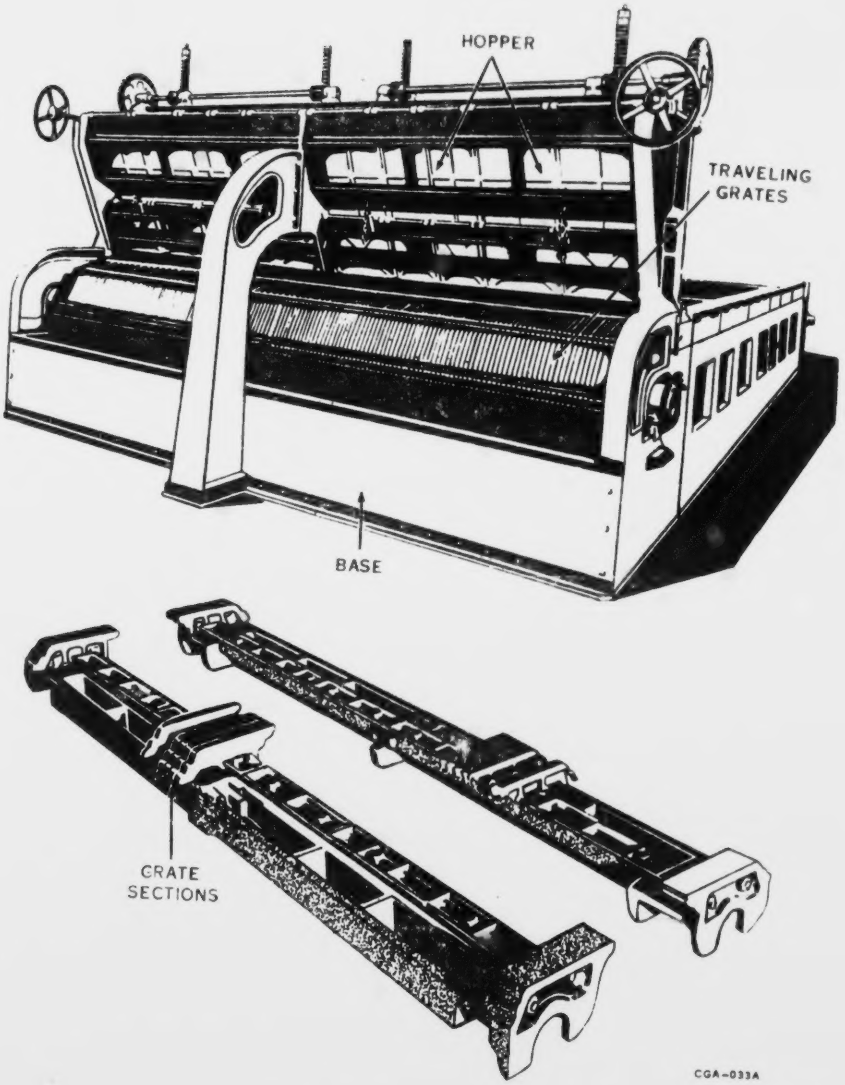

HOPPER
TRAVELING GRATES
BASE
GRATE SECTIONS
CGA-033A

Figure 5-8. Traveling Grate Stoker with Detail of Grate Bars and Keys

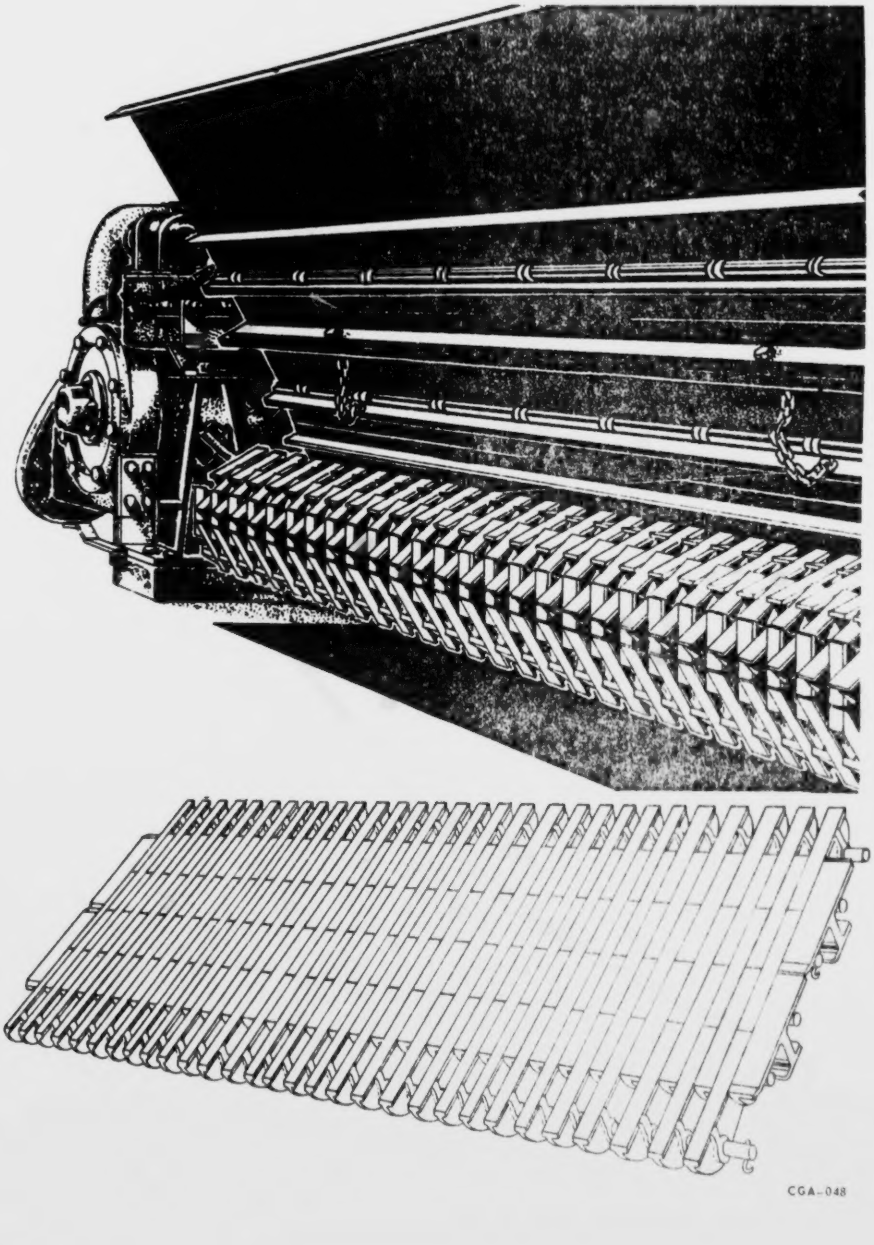


Figure 5-9. Chain Grate Stoker and Section Showing Links

### Traveling Grate

In the traveling grate, the grate sections are not under a driving load. They are made of cast-iron grate bars to which are attached small cast-iron castings called keys. These keys make up the grate surface. Grate bars are connected to an endless carrier chain driven from the front end of the stoker (see figure 5-8).

### Chain Grate

In the chain grate stokers, staggered links made of cast iron are joined by steel rods which span the width of the stoker. This assembly forms an endless chain which is driven by sprockets located at the front of the stoker. An idler drum is provided at the rear. An essential difference between the chain grate and the traveling grate is the shearing action created as the chain goes over the drum. The scissor-like action of the links help break loose any clinkers which adhere to the grate surface. Because of this shearing action, the chain grate is adapted to burn coals that tend to form clinkers (see figure 5-9).

Stokers of this design successfully burn coals which do not require agitation. They are most adaptable for use with lignites, small sizes of anthracite and free burning bituminous coal.

## Overfeed Stokers

In the overfeed stoker, see figure 5-10, coal reaches the fuel bed from above. To that extent, spreaker stokers can be considered overfeed stokers. Another type is the overfeed bibrating grate stoker.

One common design of this unit consists of an entirely water-cooled stoker which feeds and moves the coal down to an inclined grate by brief, periodic vibration of the grate. Holes and light spots in the fuel bed are prevented by the vibratory action which, when properly adjusted, produces even fuel distribution.

### Components Fuel Bed

A refratory lined, adjustable feed gate, which forms part of the hopper front, and an ash dam plate permits adjustment of the fuel bed depth.

### As Dam Plate

A stationary or adjustable ash dam plate regulates ash discharge. Ash passes continuously over the dam plate from which it is dropped to an ash hopper below.

### Air Supply

A fan discharging into a zoned air chamber supplies primary air. Damper controlled air inlets to each zone provide proper combustion. Air enters the fuel bed through tuyeres formed of grate blocks embracing the water-cooled grate tubes. This provides a water-cooled furnace bottom. Overfire air, injected through nozzles in the front arch, provide necessary turbulence and additional oxygen for complete combustion. This air is usually supplied by a separate blower.

### Vibratory Motion

A mechanical vibrator provides the intermittent vibrating motion. Combustion control determines vibration frequency. The usual range of vibration is from 2 to 5 seconds at a frequency of once every 1/2 to 2 minutes. The amplitude of the vibration is fixed (about 1/8 inch). The vibration produces a reciprocating rectilinear grate movement which helps move the coal down the grate.

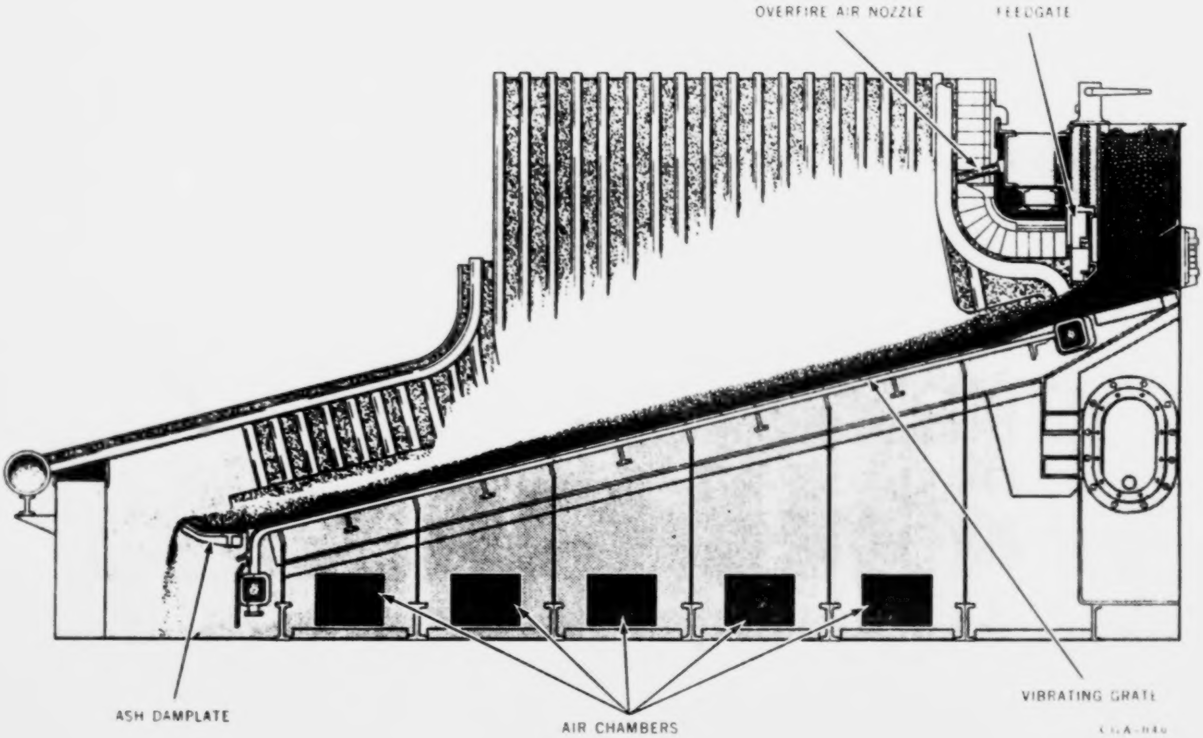


Figure 5-10. Vibrating Grate Stoker with Continuous Ash Discharge

## Pulverized Coal Burners

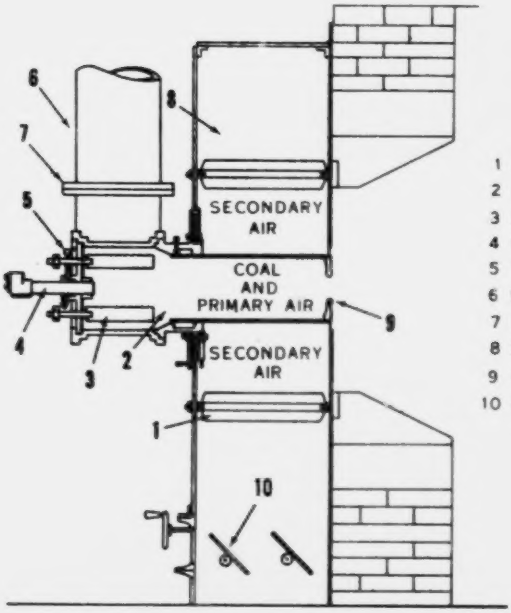
Pulverized coal burning equipment, see figure 5-11, is designed to burn coal in suspension, which has been reduced to a fine powder. Therefore, a pulverized coal burning system must have in addition to the burner, the equipment necessary to properly prepare and transport the fuel to the burner.

### Fuel Preparation and Handling Systems

There are two main types of coal preparation systems: the bin or storage system and the direct firing or unit system.

When using the bin system, coal is dired and pulverized in a central fuel preparation plant and pneumatically conveyed to storage bins before it is actually needed. This system is not in general use today since stored pulverized coal presents a fire hazard because of the possibility of spontaneous combustion.

In the unit system, coal is prepared in unit pulverizers as it is required. Large installations usually have several pulverizers to allow for flexibility in handling varied load demands. The coal preparation and handling components of a unit system are: air heater, pulverizer fan, feeder, and pulverizing mill.



1 ADJUSTABLE SECONDARY-AIR GUIDE VANES
2 NOZZLE
3 ADJUSTABLE PRIMARY AIR AND COAL GUIDE VANES
4 IGNITION AND COAL SPREADER TUBE
5 SPREADER ADJUSTING SCREW
6 PRIMARY-AIR AND COAL INLET CHAMBER
7 FLANGE CONNECTION
8 SECONDARY AIR CHAMBER
9 COAL SPREADER
10 SECONDARY-AIR DAMPERS

Figure 5-11. Turbulent Type Pulverized Coal Burner

AIR HEATER. These normally utilize steam or flue gas to heat the air that is required to dry the coal in the pulverizer. Air inlet temperature is varied depending on the moisture content of the coal. The coal-air mixture temperature at the pulverizer exit will range from 120°F to 250°F, depending upon the type of coal used. For bituminous coal, the temperature should be approximately 150°F.

PULVERIZER FAN. These fans, which supply the primary air used to dry and convey the pulverized coal, may be either the suction type or the pressure type.

The suction type fan is located on the outlet side of the pulverizer and handles a mixture of coal and air.

The pressure type fan is located in the inlet side of the pulverizer and handles only air.

FEEDER. The feeder is used to control the coal fed to the pulverizer in accordance with the load demand. Usually, it will control the flow of air so that the proper ratio of coal to air is obtained for every load.

PULVERIZING MILL. The pulverizing mill reduces the raw coal to a point where approximately 75 percent will pass a 200 mesh screen and only about 1/5 percent will not pass a 48 mesh screen. The most common types of mills are: ball and race, Raymond Bowl, Hardinge Ball and the attrition type (see Figure 5-12).

A pulverized coal burner mixes the steam of primary air and fuel with the secondary air and burns the mixture. The mixing is done just prior to or immediately after injection into the furnace. Burners produce an intimate mixing of air and fuel to promote efficient combustion and prevent loss of ignition. The most common type of burner is the flare type.

## Flare Type Burner

In this type of burner, coal and primary air enter the center pipe and is discharged through a set of vanes which break the mixture of coal and air into a number of streams. These streams assume a swirling conical shape or flare as they leave the pipe. The amount of flare can be adjusted by moving the vanes into or away from the pipe.

Primary air is supplied by the pulverizer fan and usually ranges from 15 to 20 percent of the total air required for combustion. The balance or secondary air is normally supplied by an independent fan. The secondary air is given a whirling motion by a separate set of vanes located in the windbox of the burner. Mixing of secondary air, primary air, and coal occurs beyond the burner tip. The mixing of these two streams is very turbulent resulting in a complete and intimate mixing of the fuel and air.

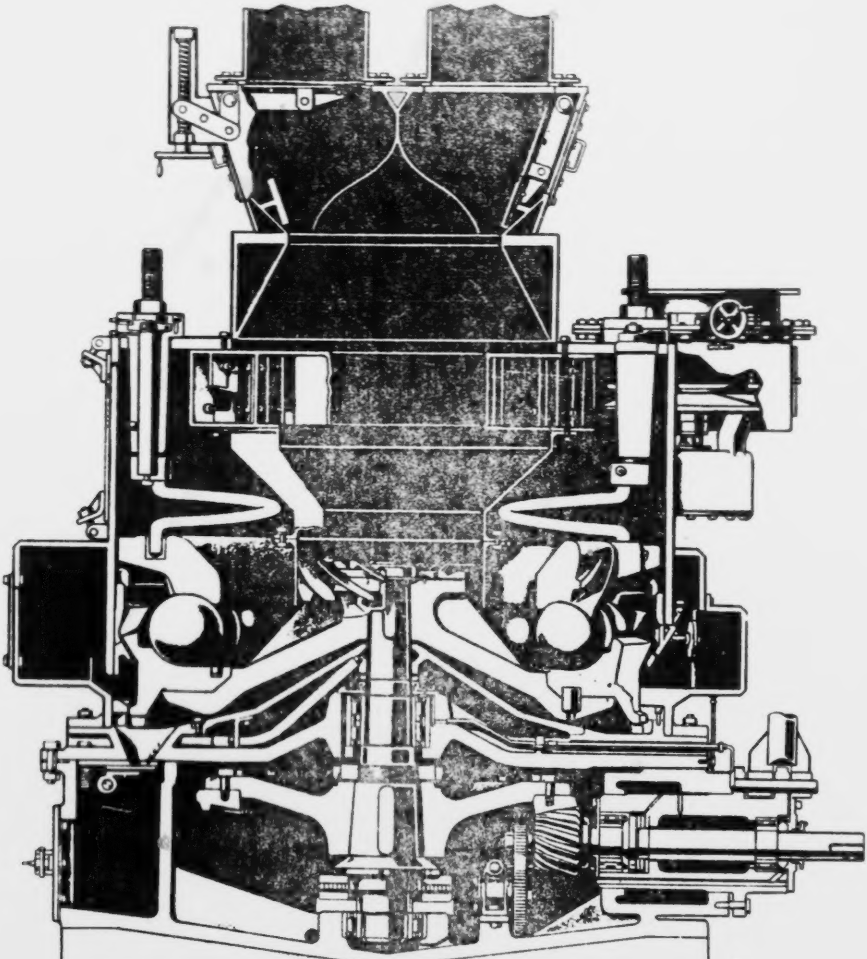


Figure 5-12. Ball and Race Pulverizing Mill

## SUMMARY

Coal is a fuel that is becoming more and more widely used by the Air Force as an alternative to the dwindling supplies of natural gas and oil. It is therefore our responsibility to make sure that the coal we burn is of the quality requested. This is done by checking the coal shipments as they arrive. By doing this we make sure that the coal we receive is what was requested.

The coal is then transferred to the unit that will burn it. The type of unit that will then feed the coal into the heating unit is determined by the amount of coal that will be burned each hour. Each type of stoker has its own field of application, depending primarily upon the characteristics of the fuel used.

## QUESTIONS

1. What type of coal is soft and friable?

2. What type of coal is high in moisture and has a woody structure?

3. How much coal should be on hand at any one time?

4. ____________________________ coal may be stored to any desired height.

5. What is the purpose of inspecting coal shipments?

6. By what means is coal fed from the hopper into the retort?

7. What type of stoker has a moving bed?

## REFERENCE

AFM 85-12, Volume 1, Operation and Maintenance of Central Heating Plants and Distribution Systems.
AFM 85-15

WORKBOOKS

J3ABR54532 001-IV-1 thru IV-5

Technical Training

# Heating Systems Specialist

# SOLID, GAS FUEL BURNERS, AND WARM AIR DISTRIBUTION SYSTEMS

April 1983

3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

DESIGNED FOR ATC COURSE USE
DO NOT USE ON THE JOB

This workbook contains practical work assignments for you to accomplish in conjunction with your study assignments. Complete each problem or work assignment in the sequence given and it will aid you in understanding and retaining the key points covered in each assignment.

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| IV-5 | Solid Fuel Burners | 5-1 |

# GAS BURNERS

## OBJECTIVE

When you have completed this workbook, you will be able to:

- Explain the characteristics of gas.
- Explain the theory of gas piping systems.
- Explain the types of gas pressure regulators and their operation.
- Explain the theory of construction and operation of gas burners.

## PROCEDURE

### EXERCISE 1

### Gas Burners

NOTE: Follow the removal, inspection, operating and adjusting procedures as outlined.

CAUTION: Observe safety precautions when installing gas burners.

1. Disconnect the gas line from the supply line fitting.

   NOTE: Make sure main gas valve is closed.

2. Disconnect electrical power line from power source.

3. Inspecting and cleaning the multiple gas burner -

   a. Check manual gas valve for free movement.

   b. Remove the burner head and venturi tube; check for cracks; clean if necessary.

   c. Make sure gas lines, pilot lines, burner ports and orifice are not clogged.

   d. Check air shutter for free movement.

   e. Check for frayed or loose wiring.

4. Installing the gas burner -
    a. Replace the burner head and venturi tube.
    b. Connect gas line from the distribution line.
    c. Turn manual gas valve to ON position and check for gas leaks using a soap solution.

5. Operating, adjusting and securing the gas burner -
    a. Open pilot line gas valve and light pilot (if applicable).
    b. Turn electrical switch to ON position (if applicable).
    c. Turn manual gas valve to ON position.
    d. Turn up thermostat (if applicable).
    e. Check and adjust gas pressure as per instructions from instructor.

6. Perform combustion analysis to assure proper fuel-air ratio.

7. Turn main burner flame down, turn off pilot flame, and explain pilotstat operation.

________________________________________________________________________

________________________________________________________________________

8. Secure the burner from operation as follows:
    a. Turn all manual and automatic gas valves to OFF position.
    b. Turn trainer electrical switch to OFF position.

9. Clean, inspect and turn in tools.

## EXERCISE 2

## Gas Burners

Complete the following statements.

1. Why is natural gas an ideal fuel?

2. What type of gas is heavier than air?

3. The gas line that delivers the gas to the point of consumption is called a _______.

4. How much pitch should a service line have?

5. How do you check for leaks on gas lines?

6. What type of regulator is usually used as an appliance regulator?

7. What safety device is used on gas fired equipment to shut off the gas to the main burner if the pilot light goes out?

8. What is the primary control for a domestic gas burner?

9. What type of pilotstat cannot be used on LPG gas systems?

10. What components are contained in the combination gas valve?

11. What determines the amount of gas burned in a gas burner?

12. The part of the gas line that feeds the gas to the orifice is called a ___________.

13. How are gas burners classified?

14. Where do the gas and air complete their mixing process in the premixing burner?

15. You inspect a gas burner and notice that the flame is mostly blue with yellow tips, what does this condition mean?

## EXERCISE 3

## Operation and Maintenance of Gas Burners

1. What areas should be examined for soot and carbon formation?

2. What is the first step in a preliminary inspection of a gas fired furnace?

3. How is gas flow supplied to the pilot light on the more expensive heating units?

4. What type of fuel would be used during production hours for a central heating plant?

5. How is carbon removed from the flame of a gas burner?

6. What conditions account for the greater share of faulty pilot light troubles?

7. What do soot formations on the interior of the combustion chamber and passages in a heating unit indicate?

8. Where does the air and gas complete their mixing with a nozzle mixing gas burner?

9. What is secondary air?

10. What are the four main types of burner ports?

11. Where is the pilot light located?

12. What is used to measure gas pressure in pounds per square inch?

13. What three devices are used to measure gas pressure?

14. Whose procedures should be followed when replacing gas burners?

15. How do you increase the output from a gas pressure regulator?

16. Why do you inspect burner orifices?

# GAS SPACE HEATERS

## OBJECTIVE

This workbook was designed to guide you in identifying the procedures for maintaining gas space heaters.

## PROCEDURE

### EXERCISE 1

### Maintaining Gas-Fired Space Heaters

CAUTION: Observe safety precautions when using hand tools and when working around gas systems.

1. Inspect tools to insure good condition and correct number.

2. Disconnect, inspect, clean, reconnect, install and operate a gas-fired heater, following these step-by-step procedures.

    a. Disconnect gas line from supply line fitting and combination temperature control.

    NOTE: Make sure main gas valve is closed.

    b. Disconnect stovepipe from heater outlet.

    NOTE: Do not disassemble the stovepipe.

    c. Lift heater and carry to work area.

    CAUTION: Do not use combination temperature control to carry heater.

    d. Remove top louvers from outer casing.

    e. Remove the blower and clean it.

    NOTE: Use rags to clean blower.

    f. Disconnect manual control from combination temperature control.

    g. Disconnect thermocouple from combination temperature control.

    h. Disconnect remote bulb from mounting bracket on space heater.

    CAUTION: Be careful with the remote bulb, do not bend or break the line.

i. Remove the combination temperature control and piping.

CAUTION: Do not bend or break remote bulb line or disassemble combination temperature control.

j. Inspect and clean the space heater.

NOTE: Check combustion chamber for corrosion and holes.

k. List step-by-step procedure for installing a new combination temperature control and have the instructor check your list before proceeding.

l. Using your step-by-step procedures, install a new combination temperature control.

m. Replace the blower.

n. Install the space heater.

o. Operate the space heater as follows:

(1) Push the control dial down and turn it to the OFF position. Place temperature dial at its lowest setting.

(2) Open the small lighter door on the side of the combustion chamber.

(3) Hold a lighted match near the pilot burner.

(4) Turn the control dial to the pilot position, depress the dial and light the pilot. Keep the control dial depressed until the pilot stays lit.

(5) Release the dial and turn to ON position.

(6) Turn the dial to "9" and the main burner will come on.

(7) Turn the temperature dial to desired setting, usually between "5" and "6". Turning toward "1" reduces temperature and toward "9" increases temperature.

(8) To turn off main burner, turn control dial handle to "PILOT." To turn off completely, depress control dial handle and turn to "OFF" and turn temperature dial to "1."

p. Perform combustion analysis to assure proper fuel-air ratio.

q. Shut down unit.

(1) Turn control dial handle to "OFF."

(2) Shut off gas supply.

(3) Unplug unit.

# EXERCISE @

## Gas Space Heaters

Complete the following statements.

1. The types of gas space heaters are ________________, _____________ and __________.

2. What type of gas space heater(s) must be vented?

3. Why must unvented space heaters be installed in a well vented area?

4. What is the purpose of casing?

5. Whose procedures should be followed for disassembling a gas fired space heater?

6. What must be done before pipe joints are assembled?

7. What must be done after installing pipe joints?

8. The size of the gas pipe necessary for the unit is dependent upon what factors?

9. Why must the exhaust vents be installed with the male ends pointing down?

10. How much pitch must a horizontal flue have?

11. Why is a draft diverter installed on a gas fired space heater?

12. What happens if too much primary air is added to a gas-fired space heater?

# UNIT HEATERS

## OBJECTIVE

When you have completed this workbook, you will be able to install and maintain a unit heater.

## PROCEDURE

### EXERCISE 1

NOTE: Using the following procedures and correct safety practices, remove, inspect, clean, install, operate and adjust a gas unit heater located in the study performance area. Draw required tools from tool cabinet. Inspect the tools to insure good condition and correct number.

1. Disconnect electric cord from power source.

2. Turn off gas.

   NOTE: Make sure gas valves on main gas lines are off.

3. Loosen brackets and remove stack.

   CAUTION: Do not allow heater to fall; loosen brackets only enough to remove the stack.

4. Remove pipe connections from main gas header to the combination gas valve on the unit heater.

5. Remove heater and take to workbench.

   NOTE: Unit heater should not be removed by just one person. Inform instructor when you are ready to take down the heater.

6. Disassemble heater as follows:

   a. Remove side cover.

   b. Remove top cover.

7. Clean heater, check fan and motor.

   NOTE: Notify instructor of your findings.

8. Install heater back on bracket.

   NOTE: Inform instructor when you are ready to install the heater.

9. Turn on gas and check for leaks.

10. Connect elecric cord to power source.

11. Operate heat using the following procedures:

    a. Depress knob on combination gas valve and turn to "pilot," depress knob and light pilot.

       NOTE: Hold knob down from 30 seconds to 1 minute.

    b. Turn knob to ON position.

       NOTE: Make sure thermostat is turned down before turning to ON position.

    c. Set thermostat for desired temperature.

12. Perform combustion analysis to assure proper fuel-air ratio.

    NOTE: If adjustments are necessary remove bottom cover to expose burners.

13. Secure heater using the following procedures:

    a. Turn down thermostat.

    b. Turn knob to OFF position.

    c. Turn main gas valve for heater to OFF position.

       NOTE: Do not turn main heater gas valve off until told to by instructor.

    d. Unplug electric cord.

# EXERCISE 2

## Unit Heaters

Complete the following statements.

1. How are unit heaters classified?

2. What is a disadvantage of using steam and hot water unit heaters?

3. Where are steam and hot water unit heaters mainly used?

4. What type of unit heater is used where individual metering of the fuel is required?

5. What type of unit heaters cannot be used in a fuel storage area?

6. The main parts of a unit heater are ______________________________.

7. How should unit heaters be located?

8. What type of unit heaters use a finned tube heating element?

9. How does the thermostat control temperature when using a hot water unit heater?

10. What monthly maintenance should be done on hot water unit heaters?

11. If a heated space fails to heat properly when using a hot water unit heater, what must you check?

# FORCED WARM AIR HEATING SYSTEMS

## OBJECTIVES

Given information, state the principles relating to the theory of operation and construction of warm air heating systems by correctly answering 80% of the questions.

Given information, explain the procedures to follow to inspect, clean, and install heating outlets to system, repair or replace duct insulating material, how to inspect and adjust distribution dampers and balance distribution system, and how to inspect and adjust air registers by correctly answering 80% of the questions.

Given information, explain the procedures to follow to inspect, remove, clean and replace heat exchangers and how to maintain humidifiers, by correctly answering 80% of the questions.

Given information, explain the purpose of air filters and the types of air filters by correctly answering 80% of the questions.

Given tools, equipment and procedures, perform a preoperational inspection and operate a warm air heating system and inspect, clean and replace warm air filters with instructor assistance.

Given tools and equipment, connect warm air outlet to system with instructor assistance.

## PROCEDURES

Complete exercises as directed by your instructor.

### Exercise 1

### Forced Warm Air Heating System

Use the following procedures when operating a warm air heating system and inspecting, cleaning or replacing warm air filters:

1. Remove jewelry.
2. Obtain necessary tools from tool locker.
3. Remove warm air filter.
4. Determine if filter is dirty. If so take appropriate measures.
5. Replace filter.
6. Have instructor determine if filters are installed correctly. If okay proceed to next step.
7. Perform preoperational inspection.
8. Turn on gas and check piping for gas leaks.
9. Plug in unit and fire it.
10. Let unit run through a complete cycle.
11. Have instructor check work.
12. Secure the unit.

## EXERCISE 2

Complete the following statements.

1. The types of warm air furnaces are ____________________ and ____________________

2. What type of furnace discharges air out the top?

3. What are the most common types of warm air furnaces in use today?

4. How many parts are there to a warm air furnace? What are they?

5. What part of a warm air furnace is considered to be the primary heating surface?

6. Whose procedures should be followed when inspecting and maintaining a warm air furnace?

7. How does cold air affect the operation of a chimney?

8. How should a warm air furnace be installed?

9. Before installing a heat exchanger, what should be done?

10. How much pitch should a horizontal vent pipe have?

11. If a chimney has a blower assisted draft, what is the shortest it may be?

12. How much free air opening must a warm air furnace have?

13. What controls are in a combination control?

14. What type of humidifier contains a float?

15. What is the sensing element used in a humidstat?

16. For maximum efficiency and comfort, a fan control setting should be ______________

__________________________________________________________________

17. Locate figure 4-2. What device controls the operation of the fan motor?

18. Locate figure 4-3. How much voltage is supplied to the gas valve?

19. Locate figure 4-4. Which terminal of the oil burner primary control supplies power to the oil burner?

20. Before starting an oil fired warm air furnace, what should be done first?

21. What is the main difference between the types of warm air systems?

22. What type of warm air system is designed to "blanket" the area to be heated?

23. When using the perimeter loop system, what purpose does it serve to bury the ducts in the concrete slab?

24. How is air velocity reduced through the registers on a perimeter radial system?

25. What type of warm air system is not recommended for use by the Air Force?

26. What advantage does an extended plenum system have over the perimeter systems?

27. What is the purpose of the plenum chamber or bonnet?

28. How often should air filters be checked?

## Exercise 3

## Connecting Warm Air Outlets to System

PROCEDURES

1. Remove all jewelry.
2. Unplug furnace from power source.
3. Remove screws holding plenum to furnace.
4. With the assistance of a classmate, lift plenum chamber from furnace and set on to workbench.
5. Using duct tape in locker repair holes in insulation as needed.

   STOP: Inform instructor that you have reached this point.
6. When told to, reinstall plenum chamber on furnace and put screws back in.
7. Return tools to locker.
8. Clean up work area.
9. Inform instructor upon completion.

# SOLID FUEL BURNERS

## OBJECTIVE

This workbook was designed to guide you in identifying the procedures for maintaining solid fuel burners.

## PROCEDURES

### EXERCISE 1

### Solid Fuel Burners

Complete the following statements.

1. What type of coal is smokeless and burns with a short blue flame?
2. What type of coal will ignite spontaneously when piled or stored?
3. What major effect does moisture have on coal?
4. What is ash?
5. Why is sulfur an undesirable element?
6. How much coal must be on hand at any one time?
7. If coal is improperly stored, what can it cause?
8. What is the mazimum height that bituminous coal may be stored?
9. What is the maximum height that anthracite coal may be stored?
10. Who should approve stockpiling of bituminous run-of-mine coal over 13 feet?
11. Why is 20 feet left between stockpiles of coal?
12. Why should a bulldozer never be used to move coal?

13. At what temperature should a coal pile be moved to avoid spontaneous combustion?

14. Why should water not be sprayed onto a pile of coal that is on fire?

15. What is the purpose of inspecting coal shipments?

16. What must be done if coal is shipped in an unauthorized type of railroad car?

17. What is the maximum amount of coal that should be considered lost or stolen?

18. How much coal should be collected for a coal sample?

19. If 10 coal cars are sampled, how much coal should be taken from each car?

20. How are mechanical coal stokers classified?

21. How would a stoker that burns 120 lbs of coal per hour be classified?

22. What are the types of underfeed stokers?

23. What is the purpose of the hopper?

24. Locate figure 5-3. What type of stoker is it?

25. What purpose do the tuyeres serve?

26. Multiple-retort stokers are always _______________ and are used on _______________.

27. What type of stoker is in figure 5-4?

28. Where does secondary air come from when burning with coal?

29. What determines the heat output of a stoker?

30. What are the types of spreader stokers?

31. What determines the rate of feed on the overthrow reciprocating plate-feed stoker?

32. What type of stoker is it where coal starts burning in suspension but completes its burning process on the fuel bed?

33. Traveling grate and chain grate stokers differ only ________________________________.

34. How are traveling grate stokers constructed?

35. What advantage does the chain grate stoker have over the traveling grate stoker?

36. What type of stokers can be considered overfeed stokers?

37. What is the purpose of using a vibrating bed on the overfeed stoker?

38. Using figure 5-10 as reference, explain the purpose of the air chambers.

39. At what frequency is the usual range of vibration for the mechanical vibrator?

40. How does a pulverized coal burner burn coal?

41. What is the purpose of the pulverizer fan?

42. What type of stoker has a moving fuel bed?

## EXERCISE 3

### Operation and Maintenance of Gas Burners

1. What areas should be examined for soot and carbon formation?

2. What is the first step in a preliminary inspection of a gas fired furnace?

3. How is gas flow supplied to the pilot light on the more expensive heating units?

4. What type of fuel would be used during production hours for a central heating plant?

5. How is carbon removed from the flame of a gas burner?

6. What conditions account for the greater share of faulty pilot light troubles?

7. What do soot formations on the interior of the combustion chamber and passages in a heating unit indicate?

8. Where does the air and gas complete their mixing with a nozzle mixing gas burner?

9. What is secondary air?

10. What are the four main types of burner ports?

11. Where is the pilot light located?

12. What is used to measure gas pressure in pounds per square inch?

13. What three devices are used to measure gas pressure?

14. Whose procedures should be followed when replacing gas burners?

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Given information, state the principles relating to the theory of operation and construction of warm air heating systems by correctly answering 80% of the questions.

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Given tools, equipment and procedures, perform a preoperational inspection and operate a warm air heating system and inspect, clean and replace warm air filters with instructor assistance.

Given tools and equipment, connect warm air outlet to system with instructor assistance.

## PROCEDURES

Complete exercises as directed by your instructor.

### Exercise 1

### Forced Warm Air Heating System

Use the following procedures when operating a warm air heating system and inspecting, cleaning or replacing warm air filters:

1. Remove jewelry.
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3. Remove warm air filter.
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6. Have instructor determine if filters are installed correctly. If okay proceed to next step.
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10. Let unit run through a complete cycle.
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PROCEDURES

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5. Using duct tape in locker repair holes in insulation as needed.

   STOP: Inform instructor that you have reached this point.

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7. Return tools to locker.
8. Clean up work area.
9. Inform instructor upon completion.

STUDY GUIDE
J3ABR54532 001-V-1 thru V-5

Technical Training

# Heating Systems Specialist

# Hot Water Heating Systems

May 1983

3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

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# EXPLANATION OF TERMS

ABSOLUTE ZERO -- Where molecular activity ceases (459.69°F).

ABSORPTION -- Process of absorbing, to take in, make a part of.

ACCESSORIES -- Items not essential, but adding to the convenience or effectiveness of something else.

ACCUMULATE -- Collect, to increase in quantity.

ADJUSTMENT -- To regulate, to bring to a more satisfactory state.

AGITATOR -- Device for shaking or stirring.

ALIGNMENT -- Putting into precise position, proper positioning or state of adjustment of parts.

ALTITUDE -- The vertical elevation of an object above sea level.

ANALYSIS -- Identification or separation of ingredients of a substance, separation of a whole into its component parts.

ANALYZER -- Device used in analysis.

ANEMOMETER -- Instrument for measuring and indicating the force or speed of the wind.

ANTHRACITE -- A hard, shiny coal.

AQUASTAT -- A controlling device actuated by water temperature.

ASBESTOS -- A fire-resistant material.

ASPHYXIATION -- Death because of lack of oxygen.

ASPIRATOR -- Device used to create a suction.

ATMOSPHERIC -- Of or relating to the atmosphere.

ATOMIZATION -- Act of atomizing, breaking into fine particles.

AUTOMATIC -- Self acting.

AUXILIARY -- Providing help, functioning in a subsidiary capacity.

BAFFLE -- Use to direct flow of gases, steam or water.

BEARING -- A machine part in which a shaft or pin turns.

BIMETALLIC -- Composed of two different metals.

BINARY -- Something constituted of two things or parts.

BITUMINOUS -- Soft coal.

BLOWDOWN -- Discharge, drain partially.

BOILER -- the part of a steam generator in which water is converted into steam and consists of metal shells and tubes.

BTU -- British thermal unit, unit of heat measurement.

BURNER -- Part of heating unit which produces flame.

CAKING -- To form or harden into a mass.

CALIBRATION -- To determine, a mark of graduation, the act or process of calibrating.

CAPACITY -- Measure of content, maximum output.

CARBON -- An essential part of coal and oil.

CARBON DIOXIDE -- A gas consisting of one part carbon and two parts oxygen ($CO_2$).

CARBON MONOXIDE -- A gas consisting of one part carbon and one part oxygen (CO).

CATHODIC PROTECTION -- Reduction or prevention of corrosion of a metal surface using an electrical current flow.

CELSIUS -- Thermometric scale, the interval between freezing and boiling is divided into 100 degrees.

CENTIMETER -- Metric measurement equaling 0.39 inch; 0.01 of a meter.

CENTRIFUGAL -- Going or acting in a direction away from a center or axis.

CHARACTERISTIC -- Trait, qualities or properties.

CHIMNEY -- Vertical structure enclosing a flue that carries off combustion gases.

CIRCUIT -- The complete path of an electrical current usually including the source of electric energy.

CIRCULATE -- To move, usually in a circle, circuit or orbit.

CLASSIFICATION -- Division of a larger category.

CLASSIFIED -- Divided into classes.

COEFFICIENT -- A number that serves as a measure of some property or characteristic.

COMBINATION -- Two or more, together.

COMBUSTION -- Burning.

COMPENSATING -- Making up for something.

COMPONENT -- A part of.

COMPOSITION -- Made up of.

CONCENTRATION -- Strength (as in strong tea).

CONDENSATION -- Act of steam turning back into water.

CONDUCTION -- The act of conveying heat through an object.

CONDUCTIVITY -- Ability to conduct.

CONSTANT -- Always or lasting.

CONSUMER -- A unit which uses steam or hot water.

CONSUMPTION -- The usage of steam or hot water.

CONTROL -- Having power over.

CONVECTION -- The act or process of conveying.

CORROSION -- Act of eating away by degrees.

COUNTERWEIGHT -- An equivalent poundage.

CSG -- Commercial Standard Grade (grades of oil).

CYCLE -- A sequence of a recurring succession of events.

DAMPER -- A plate used to regulate the flow of air or gases.

DE-ENERGIZE -- Remove the energy from.

DEMARCATION -- The set limits of.

DENSE -- Having high opacity, crowding together of parts, thick.

DESIGN -- Plan or purpose.

DETERIORATION -- The loss of strength, form or usefulness; to grow worse in quality.

DIAMETER -- A straight line through the center of a circle.

DIAPHRAGM -- Thin membrane divider or partition.

DIFFERENTIAL -- The difference between two points.

DIFFUSERS -- Device used to regulate velocity.

DIFFUSING -- The act of regulating the velocity of.

DILUTES -- Reducing the strength of.

DISASSEMBLING -- Taking apart.

DISSIPATE -- To cause to spread out or spread thin to the point of vanishing.

DISTILLATE -- Light grade oils produced by distillation.

DISTINCTIVE -- Having or giving style.

DISTRIBUTION -- Giving out or supplying portions of.

DOMESTIC -- Relating to the home or family.

DOWNDRAFT -- Supply of air received down through a chimney.

DRAFT -- A supply of air for combustion, a current of air in a closed-in space.

EFFICIENCY -- Measurement of operation or ability.

ENERGIZE -- Give energy to.

EQUALIZE -- To make equal.

EQUILIBRIUM -- Balance.

EQUIPMENT -- Implements used in an operation or activity.

ESSENTIAL -- Necessary.

EXCESSIVE -- Going beyond a limit.

EXCHANGER -- Device used to change heating mediums.

EXHAUST -- Already used once, to discharge, to draw off.

EXPANSION -- Increase in size or volume.

EXTINGUISHED -- Put out or killed.

FAHRENHEIT -- A thermometric scale on which the boiling point is 212° and freezing is 32°.

FERRULE -- Ring or metal put around a slender tube or shaft to strengthen it or prevent it from splitting.

FIXED CARBON -- Nonvolatile carbon in coal and oil.

FLARED -- A spreading outward.

FLEXIBLE -- Bendable or pliable.

FLUCTUATION -- Changing from a norm.

FLUE -- An enclosed passageway for conveying combustion gases to the outer air.

FLUE GAS -- Combustion gas.

FURNACE -- Where initial combustion and burning of fuel takes place.

GAUGE -- Instrument with a graduated scale for measuring or indicating quantity.

GRAVITY -- Force that draws objects toward the center of the earth.

GROUNDING -- The act of or an object that makes an electrical connection with the earth.

HEADER -- Pipe or tube shared by two or more objects or devices.

HOPPER -- Usually funnel-shaped receptacle for delivering coal.

HORIZONTAL -- Parallel to the horizon.

HUMIDIFICATION -- Act or process of using a humidifier.

HUMIDIFIER -- Device used to increase the humidity.

HUMIDISTAT -- Device used to sense humidity.

HUMIDITY -- Moisture in the air.

IGNITION -- Act of setting on fire.

IMPURITIES -- Something not pure or makes something else not pure.

INDUSTRIAL -- Relating to industry.

INERT -- Having no inherent power of action, motion or resistance.

INFILTRATION -- To pass into or through by filtering or permeating.

INOPERATIVE -- Not functioning.

INSERTION -- Act or process of inserting.

INSULATE -- Protect or cover.

INTENSITY -- The magnitude of force or energy.

INTERMITTENT -- Coming and going at intervals.

LATENT HEAT -- Heat that cannot be measured with or by a thermometer.

LIBERATES -- Sets free.

LIGNITE -- A brownish black, woody structured coal.

**LPG** -- Liquefied petroleum gases.

**LONGITUDINAL** -- Placed or running lengthwise.

**LOUVER** -- An opening provided with slanted, fixed or movable fins to allow flow of air.

**LUBRICATE** -- To make slippery, usually with grease or oil.

**MANIFOLD** -- Header.

**MANUAL** -- Operated by hand.

**MECHANICAL** -- Operated by a machine.

**MECHANISM** -- Mechanical operation or action.

**MEDIUM** -- A means of effecting or conveying something.

**MOISTURE** -- Wetness.

**NON-RECESSED** -- Not set into.

**NOZZLE** -- A projecting spout, terminal discharging pipe.

**OBSTRUCTION** -- Blockage.

**ORIFICE** -- Hole or opening.

**OXYGEN** -- A gas without color, taste or odor, and is a chemical element (O).

**PARTICLE** -- One of the minute subdivisions of matter.

**PASSAGE** -- Channel, course, tunnel or corridor.

**PERIMETER** -- The boundary of a closed plane figure.

**PERIODIC** -- Fixed interval between set times.

**PERTINENT** -- Relevant or applicable.

**PILOTSTAT** -- Control on the fuel line of a pilot.

**PIPETTES** -- A narrow glass tube into which the liquid is drawn by suction.

**PLENUM** -- An enclosed space in which the air pressure is greater than the outside atmosphere.

**POLLUTION** -- Impure or unclean.

**PORCELAIN** -- Ceramic that is hard, translucent and white.

**PRECIPITATOR** -- Device used to cause to separate or condense.

**PREDETERMINED** -- Decided or chosen beforehand.

**PRELIMINARY** -- Something that precedes.

**PRESSURE/PRESSURING** -- Force exerted over a surface divided by its area.

**PROPELLER** -- A device that drives or forces forward or onward.

**PROPORTIONAL** -- Having the same or constant ratio.

**PULVERIZED** -- Reduced to very small particles.

**PURGE** -- Clean out.

QUANTITY -- Amount (how many).

RADIANT -- Emitted or transmitted by radiation.

RADIATION -- Energy radiated in waves or particles.

RADIATOR -- Next of pipes or tubes used to heat by radiation.

REASSEMBLE -- Put back together.

RECTANGULAR -- Having or resembling the shape of a rectangle.

REFERENCE -- Consultation of sources or information.

REFRACTORY -- Heat resisting nonmetallic ceramic material.

REGULATE -- To control something.

REGULATOR -- Device which regulates.

RESPONSE -- Replay or reaction.

RESTRICT -- To limit.

RETURN -- To bring, send or come back to the starting point or place.

ROTATION -- The turning of a body on an axis.

SATURATION -- Moisturizing to the maximum limit.

SEMIBITUMINOUS -- A type of coal.

SENSIBLE HEAT -- Heat that can be felt or sensed.

SHUTOFF -- Something that stops the flow of gas, water or oil

SLAGGING -- The flowing together of coal impurities.

SMOKE PIPE -- The vent pipe used to remove smoke and gases from the firebox of a furnace or boiler.

SOLENOID -- An electromagnetic valve or switch.

SOOT -- Black substance formed by combustion or separated from fuel during combustion.

SPONTANEOUS -- Without external stimulus.

STABILIZER -- Substance that prevents chemical change.

STATIC ELECTRICITY -- Electricity produced by atmospheric conditions or various natural or man-made electrical disturbances.

STATIONARY -- Fixed, not moving.

STOKER -- A machine for feeding a fire.

STRAINER -- Device used to remove impurities from water and steam lines.

STRATIFICATION -- Act or process of stratifying.

SUPPLY -- To provide for.

SYNTHETIC INTOXICATION -- Artificial intoxication.

SYSTEM -- An assemblage or combination of things or parts forming a complex or unitary whole.

TEMPERATURE -- A measurement of heat in degrees Fahrenheit or Celsius.

TENSION -- Condition or degree of being stretched to stiffness.

THERMOCOUPLE -- Thermoelectric couple used to measure temperature differences.

THERMOPILE -- Multi-thermoelectric couples.

TRANSFER -- Move something from one place to another.

TROUBLESHOOTING -- Looking, in a logical sequence, for a problem.

TURBULENT -- Causing unrest, violence or disturbance.

TUYERES -- Nozzles through which an air blast is delivered.

VAPORIZATION -- Act, process or state of being vaporized.

VAPORIZING -- To convert, by heating or spraying, into a fine mist or vapor.

VELOCITY -- Quickness of motion.

VELOMETER -- Device used to measure velocity.

VENTURI -- Funneled tube used to measure flow.

VISCOSIMETER -- Device used to measure viscosity.

VOLUME -- Space occupied, measured in cubic units.

VOLUMETRIC -- Relating to the measurement of volume.

WATER -- a liquid that is colorless, odorless, poor conductor of electricity, freezes at 0°C and boils at 100°C.

3770 Technical Training Group
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Sheppard Air Force Base, Texas

SG J3ABR54532 001-V-1

# HOT WATER HEATING AND CONTROLS

## OBJECTIVES

Using information given, explain the principles of operation of low/medium temperature hot water boilers by correctly answering 20 out of 25 questions.

Given procedures and trainer, install, operate, and maintain a centrifugal pump with no more than two instructor assists.

## INTRODUCTION

Hot water systems are systems in which water is heated at a central source, circulated through a system of pipes, and sent through units that transfer the generated heat to the surrounding air. These systems are considered very useful carriers of heat. Each system is classified according to their operating temperature such as low, medium and high temperature. The water temperature for low-temperature hot water heating systems ranges from 100 to 220 degrees, for medium temperature 220-300 degrees and for high temperature water 350-400 degrees.

Because of the higher temperatures involved with high temperature water it must be taught separately form low and medium temperature systems. Therefore, high temperature water will be discussed in another block.

## INFORMATION

## PRINCIPLES OF OPERATION

Low temperature water systems utilize low-temperature water as the heat source. Because of its relatively low energy level, low temperature water is usually applied direct when used for space heating.

Domestic hot water systems are classified as direct or indirect. In direct systems, water is heated by hot combustion gases from a burning fuel applied directly to the heating surfaces, or by electric heating elements. In direct systems, sometimes called secondary systems, the water is heated by steam or hot water applied to the heater surfaces, see Figure 1-1. Indirect systems are, for the most part, limited to individual buildings and homes; direct systems are suitable for any size installation or quantity requirement.

### Natural Circulation System

Natural circulation systems are similar in principle to gravity warm air distribution systems. A fire in the boiler heats the water. The hot water, like hot air, rises to the top of the boiler and flows up into a supply main (large pipes) that slopes upward gradually around the basement perimeter. Smaller pipes extend upward vertically from the supply main to one end of each radiator, to let the hot water flow up into them. At the opposite end of each radiator, another pipe (connected at a low point) carries the cooled water down to the return main (a large pipe that slopes downward around the basement perimeter and eventually leads into the bottom of the boiler). Thus, watre heated in the boiler floats up into the radiators and heats the rooms. And, as it heats the rooms, it cools off and becomes heavier—just like the air in a gravity hot-air system, flowing down the return pipes and back into the boiler to start all over again.

Velocity or flow through the piping is low. Therefore, the pipe size must be relatively large to prevent the friction loss.

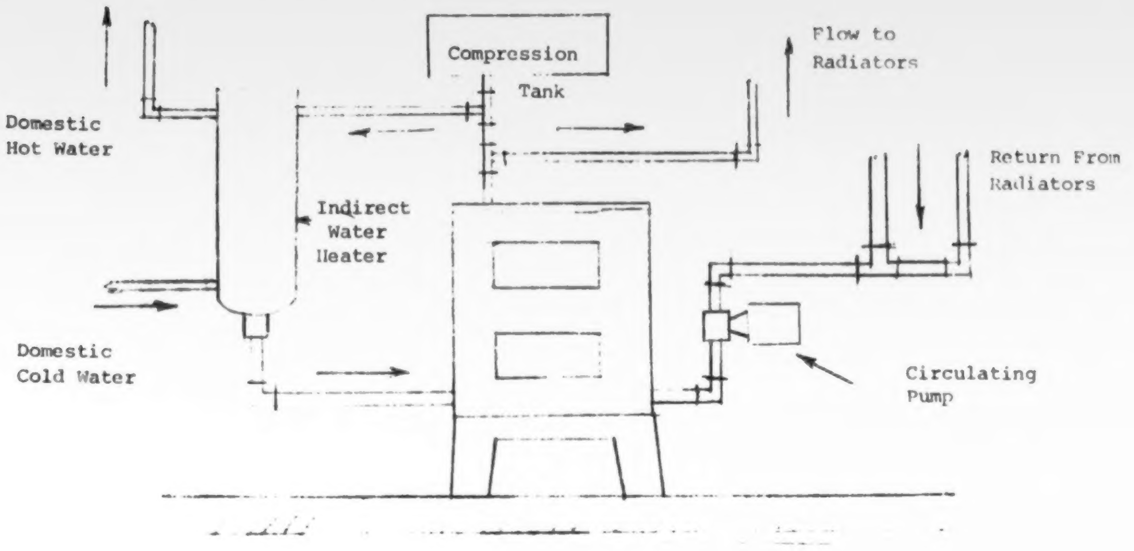
Domestic Hot Water
Compression Tank
Flow to Radiators
Return From Radiators
Indirect Water Heater
Domestic Cold Water
Circulating Pump

Figure 1-1. Indirect Domestic Water Heating

Forced Circulation System

The forced hot-water system is similar to the gravity system; the main difference is in the method of circulation. The supply main is connected to the top of the boiler and the return main to the bottom, as usual, but the water is sent through the system by a centrifugal pump.

## CENTRIFUGAL PUMPS

In this type of pump, a rotating impeller or runner gives velocity to the fluid, and centrifugal force pushes it from the impeller. See Figure 1-2. These pumps are compact, discharge at a uniform rate of flow and pressure, contain no valves or pistons, and can handle a variety of fluids according to their design. The number of impellers determines whether a centrifugal pump is of single-stage, two-stage or multi-stage design. A single-stage pump has only one impeller. A two-stage pump has two, the first discharges into the suction of the second. Multi-stage pumps have three or more impellers and are ued in high pressure operation. There are two types of impellers, an open face impeller and a closed face impeller. These impellers are either single- or double-suction. In the double-suction type, water enters the eye of the impeller from both sides. See Figure 1-3.

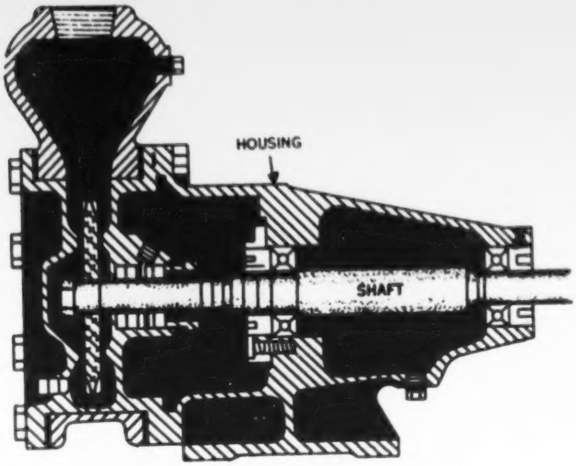
HOUSING
SHAFT

Figure 1-2. A Centrifugal Pump

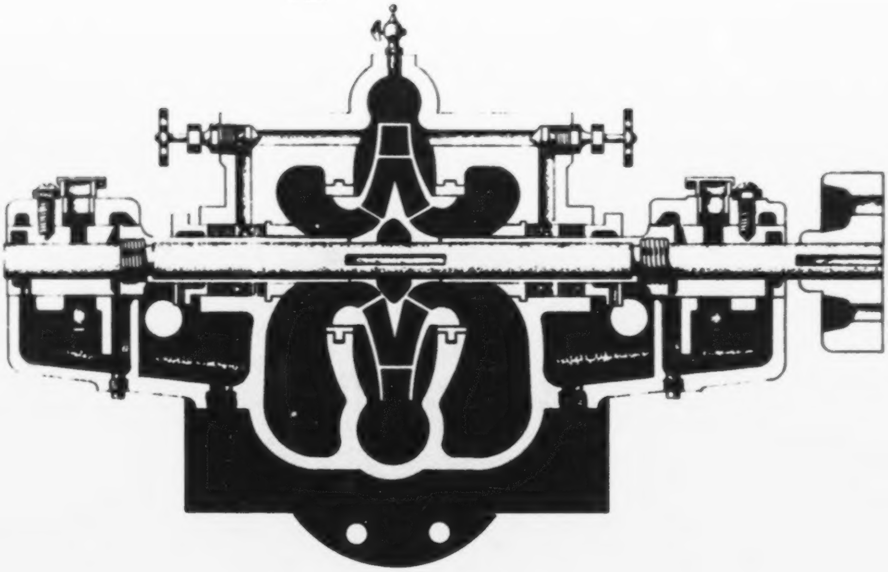

Figure 1-3. Single-Stage Double-Suction Centrifugal Pump

The main parts are a rotating element called the impeller (see Figure 1-4) or runner, the casing, the shaft, and the bearings that support the shaft. The impeller admits the water through the center (eye) and discharges it through the outer rim. The casing contains the inlet and outlet passages for the water. It guides the water from the inlet connection into the impeller and away from the impeller to the discharge connection. The shaft supports and drives the impeller and is, in turn, supported by the bearings. In addition to the essential parts that we have mentioned, shaft sleeves, stuffing boxes and wearing rings are also usually used in centrifugal pumps.

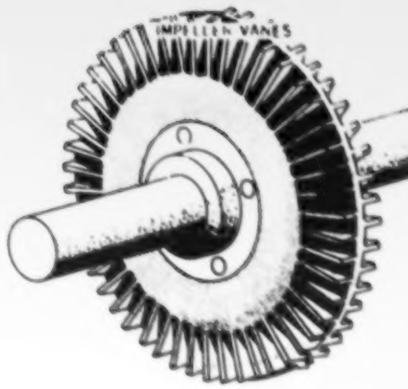

Figure 1-4. Impeller

Maintenance of Centrifugal Pumps

Never run a centrigual pump dry, because liquid is necessary to lubricate the internal surfaces. Never throttle the pump suction to regulate the flow of water, because cavitation will result. Do not permit the pump to stand idle for long periods of time. It should be operated at least once a week. The following paragraphs discuss preventive maintenance inspection and pump maintenance requirements pertinent to centrifugal pumps.

DAILY INSPECTION. Each day, you should inspect the centrifugal pump for abnormal noise and vibration; abnormal pressure and flow conditions; excessive or inadequate packing leakage (water-cooled bearing); hot bearings; and hot stuffing box.

SEMIANNUAL INSPECTION. Every six months, you should check alignment of the pump and driver with the unit at a standstill and normal operating temperature; check shaft sleeves for scoring; replace packing by cutting the packing diagonally and stagger pieces installed around the shaft, if required; drain the oil from oil-lubricated bearings, flush and refill with clean oil; and check grease-lubricated bearings. Do not over grease the bearings. When adding grease, remove the drain plug or use a safety fitting to prevent over greasing.

ANNUAL INSPECTION. On a yearly basis, the pump is dismantled, a complete inspection is performed, and the following requirements are satisfied. Check the wearing ring clearances according to the manufacturer's instructions; diametrical clearance between 0.005 and 0.025 inch is usual. Examine bearings for wear, check clearances according to manufacturer's instructions, and overhaul, if necessary. Check shaft for scoring, corrosion, or wear at the seals, and also for proper alignment. Check impellers for corrosion, erosion or excessive wear. Check and calibrate pressure gauges, thermometers and flow meters. Inspect suction and discharge strainers.

Repair and replace defective parts found during the annual inspection. Replace wearing rings when clearances are twice the original, or if the leakage appreciably reduces the capcity and head of the unit. Replace worn shaft sleeves or rebuild them.

Install centrifugal pumps according to manufacturer's instructions.

## TYPES OF BOILERS

The boiler is where the water is heated. The boiler is the same type as that used for low-pressure steam generation. Low temperature hot water boilers may be classified according to the fuel used (coal, oil, gas), the application (what it is used for), the design (fire-tube, water-tube), and the material (cast iron or steel). For simplicity, we will classify them as to the material used: cast iron or steel.

Cast-iron boilers are shipped in sections and assembled at the installation site. Small boilers, however, are factory-assembled and shipped as a unit. Each section is actually an individual boiler connected to supply and return headers. The supply header is located at the top, center and the return header, laterally, near the foundation, of the boiler. Heated water rises through the vertical sections from the return headers.

Cast-iron heating boilers may be designed for operating pressures not exceeding 160 psig, or temperatures not exceeding 250°F. Normally, they are designed for 30 psig working pressure. See Figure 1-5.

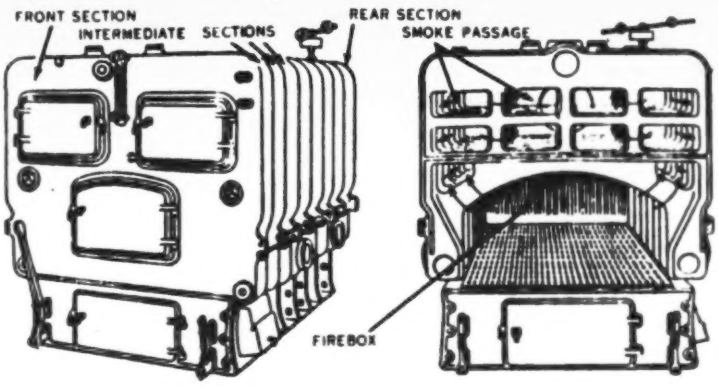

Figure 1-5. A Square Sectional Cast-Iron Boiler

Steel heating boilers may be of the fire-tube type in which the combustion gases pass through the tubes, while water surrounds them; or the water-tube in which the water passes through the tubes, while the gases circulate around them.

The ASME code for low-pressure heating boilers limits the maximum allowable working pressure to 160 psig for steel heating boilers. Normally, they are designed for 30 psig working pressure. Most steel hot water boilers are constructed in two sections. One section consists of the water jackets, combustion chamber, and smoke passages. These components are either welded or riveted together as a unit. The other section consists of the base and either the grates or burner, and is constructed according to the type of fuel used. Another steel boiler is a horizontal unit of the portable-type having an internal firebox surrounded by water lanes. It rests either on a cast-iron or a brick base. The front part of the boiler rests on a pedestal.

## BOILER ACCESSORIES

All boilers have certain accessories for safety and ease of operation. The various accessories used include the following:

### Pressure Relief Valve

Every hot water boiler must have a relief valve with a capacity adequate for the gross output of the boiler. The valve, which is connected to the top of the boiler, is necessary to prevent the operation pressure from exceeding the maximum permissible level.

### Thermometer

A Thermometer must be placed in the upper part of the boiler to indicate the water temperature.

### Pressure Gauges

These are connected to the top of the boiler and indicates the water pressure in the boiler and system in pounds per square inch. This gauge must have a pressure capacity at least twice the maximum operating boiler pressure or permissible altitude, to indicate the operating pressure.

### Tridicator

This gauge combines a pressure gauge, water temperature gauge and an altitude setting. The purpose of this gauge is to show the level of water proper for an actually present in the system. This gauge has three needles, one red and two black. One of the black needles is used for the temperature gauge. The other black needle is used for the water level that is required for the highest heat consumer in the building. The red needle indicates the actual level of water in the system and varies with changes in water content. When the red needle is over the black one, the system is properly filled. In pressure systems, the amount of water is automatically controlled by a pressure reducing valve. By reading the tridicator, you can tell whether the valve is operating correctly.

### Aquastats

Limit controls for hot water installations are commonly called aquastats. The function of an aquastat is to reduce operating cost by eliminating unnecessary firing. Aquastats may be of the mercury type, such as illustrated in Figure 1-6 or contain a bimetal element. Most aquastats are of the immersion type. This type has its sensing element inserted in an immersed copper well. The sensing element in the immersion well may be a metallic spring or a liquid filled bulb. At the temperature setting of the instrument, the rotation of the spring or expansion of the liquid, will rotate the mercury switch and open or close the circuit according to the type of service the switch is to perform. Since a mercury switch is used, the instrument must be installed and maintained in a level position or it will not operate properly. The temperature at which the switch will operate is set on the temperature scale with the temperature setting screw. Figures 1-7 and 1-8 are typical locations of the immersion type aquastats for hot-water systems.

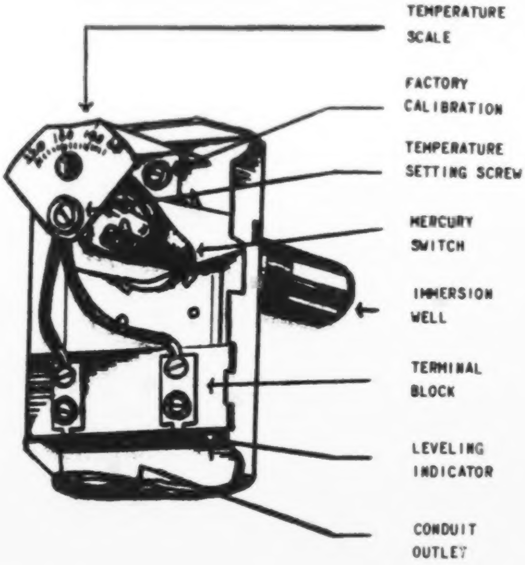

Figure 1-6. A Typical Immersion-Type Aquastat

The immersion aquastat can be removed from its copper well for repair or replacement without shutting down and draining the system.

### Outlet Connection

The outlet connection should be as large as the manufacturer's tapping. Some installations use a dip tube to keep air out of the supply main. The dip tube, an extension of the outlet pipe, projects into the boiler and causes a dead space at the highest part (where the temperature is higher). The air that separates from the boiler water into the dead space flows through proper connections ito the expansion tank. If the expansion tank is not directly connected to the boiler, release the air through an automatic air vent.

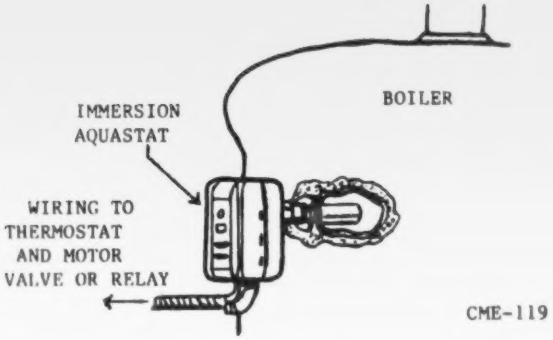
BOILER
IMMERSION AQUASTAT
WIRING TO THERMOSTAT AND MOTOR VALVE OR RELAY
CME-119

Figure 1-7. Installation Diagram of an Immersion-Type Aquastat in a Hot-Water Boiler

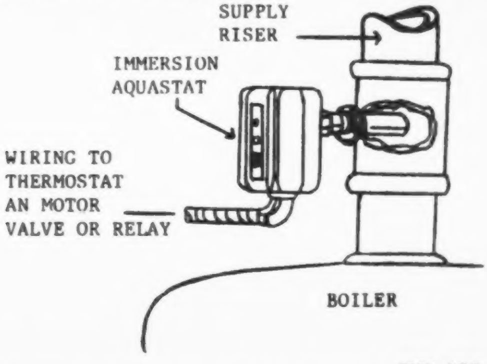
SUPPLY RISER
IMMERSION AQUASTAT
WIRING TO THERMOSTAT AN MOTOR VALVE OR RELAY
BOILER
CME-120

Figure 1-8. Installation Diagram of an Immersion-Type Aquastat in a Vertical Riser of a Hot-Water Boiler

Inlet Connection

Properly used, return connections prevent thermal shock. If water enters the boiler at a high velocity, it disturbs the thermal circulation of the boiler water and may cause sludge or sediment to pile up in the mud ring. To keep entering water at a low velocity, use a return header connection the same size as the boiler inlet. If a boiler has two return connections, use both. When more than one circulation pump is to be used, connect their discharges to a common pump discharge header before making the boiler connection; be sure that each pump has a check valve on its discharge side (between the pump and common discharge header) to prevent backflow through the pump circuit. Return header connections must be readily accessible for cleaning, draining and rodding, and must have plugged openings. Use plugged tees instead of elbows at boiler return connections to assure ample cleanout facilities.

Flow Control Valve

This is a special valve used on a forced circulation system to prevent the gravitational flow of water through the system when the circulating pump is shut off. Figure 1-9. It is located on the supply main just above the boiler. This valve operates under the same principle as the check valve, only it prevents gravitational flow of the water instead of reverse flow.

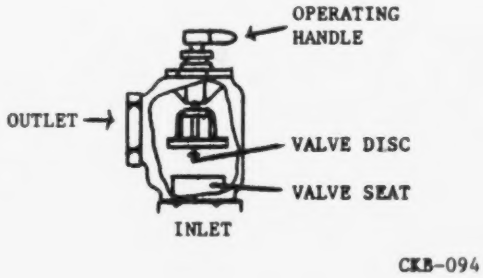
OPERATING HANDLE
OUTLET
VALVE DISC
VALVE SEAT
INLET
CKB-094

Figure 1-9. One Type of Flow-Control Valve

### Blow-off Connections

A blow-off or drain connection is placed near the hot water boiler so that the entire system can be drained through the drain valve.

### Water Supply Connections

Hot water boilers must have a water service connection in the return main, near the boiler, through which the boiler may be filled from startup and to be able to add makeup water from water that is lost throughout the system.

### Chimney and Breechings

Since a boiler usually burns a fuel it, therefore, produces exhaust gases that must be removed from the boiler. This is the purpose of a chimney and breeching.

When a boiler produces exhaust gases they leave the boiler and enter a steel chamber called a breeching. The breeching is designed and sized to direct the flow of hot gases to the chimney or stack where these gases are directed to the outside atmosphre. The size of the stack is dependent upon whether you have a natural draft system or have blowers that push and pull the gases out.

### Expansion Tanks

Every hot water heating system should have an expansion vessel installed to handle the expansion and contraction of water which occurs as its temperature changes.

OPEN-TANK SYSTEM. In open-tank systems, the expansion tank is freely vented to the atmosphere. Normally, these systems are limited to installations with operating temperatures of 180°F or less. Operation at higher temperatures, which would be near the boiling point of water, at atmospheric pressure (212°F), could be troublesome. Open tanks are usually installed at least three feet above the highest heat transmitter. The tank and connecting piping should be protected against freezing.

CLOSED-TANK SYSTEM. This system uses an air-tight tank, sealed to prevent free venting to the atmosphere. Therefore, heating systems using it can be pressurized and operated over a wide range of temperatures and pressures. Thus, when the saturation pressure is raised to correspond to the desired temperature, the system can be operated above 212°F. In operation, as heated water expands, the excess water moves into the tank and compresses the entrapped air, thereby increasing the pressure on the system. When the water temperature lowers, the water contracts, air in the tank expands, the excess water returns to the system, and the pressure drops. A closed expansion tank must be large enough to keep a reservoir of compressed air above the water level to cushion the excess water that enters. Thus, the tank must provide space for changes in both water and air volume. If the tank is too small or contains insufficient air, these undesirable conditions can occur:

—— As temperature increases, the water will expand and the system pressure may increase above the permissible level. This will cause the relief valve to open and waste water.

—— As temperature drops, the water contracts and the pressure may drop below the permissible minimum. Air will not vent from the system and additional air may be drawn in, if the high points of the system have automatic air vent valves.

The location of closed tanks depends on the type, size and design of the installation. Regardless of location, the point of junction between tank and system is under constant pressure, even when the pump is not operating. Designers consider this fact when setting up piping arrangements. When possible, connect the expansion tank by a direct pipe to the highest point of the boiler. This arrangement lets air pass easily to the tank.

In closed tanks, a water gauge glass, air inlet valve (airtrol valve), water inlet, drain and relief valves permit the operator to observe and adjust the proportion of air in the tank. In open tanks overflow and vent pipes are used instead of relief and air inlet valves.

SIZE OF EXPANSION TANKS. The expansion tank should be large enough to permit the water volume to change without causing undue strains on the equipment. When water is heated from 40°F to 200°F, its volume expands approximately 4 percent; this expansion tank must be large enough to hold 1 gallon of water for every 25 gallons that will be heated.

### Pressure Regulator Valve

A pressure-regulator valve is usually installed in the makeup or cold water line to the boiler. This valve automatically keeps the closed system supplied with water at a predetermined safe pressure. The maximum permissible pressure for a standard hot water heating system is 30 psi; therefore, the regulator valve setting should be as low as possible. Valves are usually factory set a 12 psi pressure; this equals a static head of 276 feet of water (suitable for buildings with 1, 2 or 3 stories). However, if the static head of the system is high, boilers with higher operating pressure may be required, and the regulator valve is set correspondingly higher. Maintain pressure regulator valve pressure adjusting screw by turning the pressure adjusting screw clockwise to increase the pressure. Turn it counterclockwise to decrease the pressure. The purpose of the strainer is to remove impurities form the supply line. The strainer should be removed and cleaned once each year (annually).

## PROCEDURES FOR REMOVING THE BOILER AND SYSTEMS FROM SERVICE

### Shutting Down

If the complete system is to be removed from service, proceed as follows:

—— Stop the firing equipment.

—— Shut off draft dampers to permit the boilers to cool gradually.

—— Maintain water circulation through the boiler until inlet and outlet water temperatures are equalized.

—— Stop water circulators when the water in the unit has cooled; then close boiler inlet and outlet water valves.

### Space Heating Equipment

To remove an individual radiator, convector, etc., from service in one- or two-pipe systems, be sure to stop water circulation through the unit by using the proper valve. If there is danger of freezing, drain the unit. However, in series-loop systems, do not interrrupt the water flow through a single unit, since that would stop circulation through the entire circuit. Use the damper in unit enclosure to prevent convection of air through the entire circuit.

### Draining Boiler

In order to drain boiler, proceed as follows:

—— Make sure power to boiler is off and tagged.

—— Open drain valve on expansion tank.

—— Open drain valve on boiler.

### Flushing Boiler

After water drains from boiler, proceed as follows:

—— Open raw water bypass.

—— Flush fresh water thru boiler until water runs clean.

—— When water runs clean close off bypass.

Filling the System.

Proceed as follows:

——— Close all vents.

——— Open boiler supply main valve and return header valves.

——— Open inlet and outlet valves of circulators.

——— Open all valves to radiation.

——— Open manual feed valve and feedwater until expansion tank is approxiamtely one-half full.

——— Start the circulators and establish a definite water circulation in the system. Check operation of circulators for noise, vibration, abnormal temperature, etc.

——— Begin venting the lowest radiators or space heating equipment; open vent valves (if manually operated) until all air is removed and free water starts to flow.

——— Vent the rest of the units progressively; if necessary, add water to the system to complete venting of all units as routine progresses.

——— Drain and refill the system several times to remove all grease, core sand, and other foreign material, before starting the fire for initial operation.

Preoperational Inspection

Before starting the system, perform a preliminary inspection. Inspect the installation carefully and make sure that the following requirements are fulfilled.

BOILER UNIT

——— All installation, repair and cleanup work completed.

——— All air and gas ducts and passages tight and free from obstructions; gas and air control dampers in good operating condition.

——— All piping tested for leaks, and insulated if necessary.

——— Blowdown lines properly installed and fastened, and drain valves closed; supply and return header-valves in good operating condition.

——— Water gauge glasses in expansion tank properly installed, with valves open, gauge glasses clearly visible from the operating floor, and lamps, if present, ready for operation.

——— All required auxiliary equipment (such as fuel-burning, draft, feedwater and combustion-control systems) properly installed and ready to operate; pumps lubricated and rotation tested.

——— All meters, instruments and gauges properly installed and ready for operation; pressure relief valves and limit controls properly set and in good operating conditions.

——— All access and observation doors closed.

SPACE HEATING EQUIPMENT. All installation, repair and cleanup work on radiators, convectors, pipe coils, baseboard units, etc., completed; all units ready for operation.

PIPING SYSTEM

——— All installation, repair and cleanup work completed.

—— All piping tested for leaks, adequately supported, and insulated, if required.

CONTROL SYSTEM

—— All installation, repair and cleanup work completed.

—— Thermostats, primary controls, limit controls and auxiliary controls properly calibrated and preset to operate within approved limits.

PLACING THE SYSTEM IN OPERATION. Proceed as follows:

Boiler. Light off the boiler and slowly heat system water and furnace refractory.

Initial Operation. When operating a newly filled system for the first time, heat it to a higher temperature than that anticipated for normal operations, but not above the safe limits. This procedure expels entrained air from the system water and will help vent the system. After the system has been in operation for two days, open the boiler drains to eliminate the heavy core sand and similars which tend to flow to this low part of the system. When opening drain valves or feeding makeup water to a hot water heating system, keep the water flowing slowly to prevent the excessively rapid temperature changes which cause undue stresses in the boiler. After the system has operated for about 10 days, reopen the air vents and release all air from the system. Afterwards, check the system periodically for venting requirements. When starting a panel heating installation for the first time, supply water to the panels at a temperature not more than 20°F above room temperature, or a total of 90°F. Maintain this temperature for two days; then progressively increase it, by about 5°F a day, to the normal operating temperature, but do not let it exceed 140°F. After the system has been flushed and vented, do not drain it unless an emergency requires.

Water level. When operating a hot water system, it is very important to maintain the proper water level in the expansion tank. After the water reaches normal operating temperatures and pressure, stop the manual feed valve and use only the pressure reducing valve. The reducing valve automatically maintains the system water level. Inspect the water line in the expansion tank frequently. When the system is cold, the water level should be low enough to allow the heated water to expand. Blow down the water, if required.

Pressure. Observe system pressure frequently. It gives information about unfavorable conditions such as:

—— Low Water. Below normal pressure may indicate low water.

—— System stoppages. Abnormally high pressure may indicate system stoppage from freezing or other causes.

—— Expansion Tank Completely Full. A rise in water pressure may indicate that a closed system expansion tank is completely filled, or that the air volume in the tank is inadequate for the necessary expansion.

—— Failure of Relief Valve. If the relief valve fails to operate when the system pressure rises above the determined setting, shut down the boiler immediately. If the high pressure results from an excessive fuel-burning rate, the water temperature will exceed the limit control setting, and thereby shut down the boiler and start the circulators.

Control Systems. Safe and correct operation of a hot water system depends upon proper functioning of control equipment. Periodically check operation of thermostats; primary, limit and auxiliary control; and calibration and setting.

Circulators. Circulating pumps used in hot water heating systems are usually very simply constructed. Check them carefully for abnormal noise, vibration, or excessive operating temperature. Be sure that they rotate freely and properly, and that stuffing boxes (when used) are not drawn up tightly enough to score the shaft.

Space Heating Equipment. Set valves for the maximum opening compatible with equipment size and system temperature balance. Open air vents periodically to free the equipment of air. Some hot water systems have radiator valves for closing off circulation through the radiators. Sometimes, these valves have weep holes which allow sufficient water circulation, even when the valve is closed, to prevent the radiator water from freezing.

## Normal Operation

Well designed hot water heating systems rarely present operating difficulties, if normal temperatures and pressures are carried. If rapid fluctuation or pulsation pressures should occur, check for system leaks, stoppages, and relief valve operation. The indicated pressure of a closed system may increase slightly with the increase of watr temperature. Each system has its own definite increase characteristic, determined by the water capacity of the system and the size of the expansion tank. Observe and record this characteristic when the system is in perfect operating condition. Any later deviations from the established pressure may indicate that the water level is low (if pressure decreases) or that the system is stopped or plugged (if the pressure is above normal). Watch the water level in the expansion tank.

## Advantages and Disadvantages of Low and Medium Hot Water Systems

Now that operation of the system has been discussed, and purpose and function of all components are understood, a few advantages and disadvantages may now be pointed out.

### ADVANTAGES OVER OTHER HEATING MEDIUMS

- Cleaner than systems using air as a medium.
- More uniform heat distribution than systems using air.
- Less water treatment than systems using steam.
- Safer than steam systems.
- Requires less component parts than steam systems.
- Lower installation and maintenance cost than steam systems.

### DISADVANTAGES AS COMPARED WITH OTHER HEATING MEDIUMS

- Will not produce steam efficiently.
- Not suited for large central plants.

## Maintenance Procedures

In low-temperature heating systems, there is very little water treatment required.

## SUMMARY

Hot water systems are systems where water is heated at a central source, circulated by either natural or forced circulation through a system of pipes, and sent through units that transfer the generated heat to the surrounding air.

Accessories are added to boilers for the purpose of safety and for ease of operation.

One device added to hot water systems is an expansion tank. Without it the heated water would have no place to expand and contract. Two types used are the open and closed types. In order to operate at higher temperatures a closed tank must be used.

Whenever operating, cleaning or maintaining a hot water boiler, always remember to follow manufacturer's instructions.

QUESTIONS

1. What is the temperature range for a low temperature hot water heating system?

2. How are low temperature hot water boilers classified?

3. What is the purpose of the expansion tank?

4. Where are open expansion tanks installed?

REFERENCES

1. AFM 85-12, Volume I, Operation and Maintenance of Central Heating Plants and Distribution Systems
2. AFM 85-12, Volume II, Operation and Maintenance of Space Heating Equipment and Process Heat Utilization

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SG J3ABR54532 001-V-2

# HOT WATER DISTRIBUTION SYSTEMS

## OBJECTIVES

Using information given, explain the types of hot water distribution systems and their components by correctly answering ten out of fifteen questions.

Using information given, explain the procedures to follow to install a secondary hot water heating system by correctly answering two out of three questions.

## INTRODUCTION

The hot water boiler heats the water necessary for the system to operate while the piping system directs this heated water to the point where the heat can be taken away. Once the heat has been removed, then the cooler water must then be returned to the boiler where the process starts over again. This is the purpose of the hot water heating system.

## INFORMATION

## TYPES OF SYSTEMS

The type of piping system that is used on a hot water system is dependent upon the method of circulation. This was covered earlier under boilers, but we will review their basic operation.

### Natural Circulation System.

In this type of system the water is heated in the boiler. The heated water, because it becomes lighter, flows up into the supply main which slopes upward gradually around the building. Once the water gives off some of its heat it cools and becomes heavier. It is then directed to the return line, which is sloped towards the boiler, where it goes through the same process again.

### Forced Circulation System

The main difference between the natural circulation system and the force circulation system is the method of circulation. Instead of allowing the weight difference of the water to create circulation, a pump forces the water around. Because of this, it is not necessary to slope the pipes.

The pump, usually in the return line, controls the flow of water through the system and operates whenever the room thermostat calls for heat. The method of piping the water through the radiators, however, varies in several basic ways.

### Direct Heating System

A direct heating system is one in which the water is heated by hot combustion gases from burning fuel applied directly to the heating surfaces.

### Indirect (Secondary Heating System)

In a secondary system the water is heated by another medium such as high temperature water or steam. This is done by putting the heated medium through a device called a shell and tube bundle. They travel through tubes inside while the water to be heated is around the outside. This causes the surrounding water to become heated. This heated water can now be sent out and heat a house, small building, etc.

**SERIES LOOP SYSTEM.** The series loop (Figure 2-1) is the simplest of the radiator supply arrangements. Hot water leaving the top of the boiler through the supply main shoots straight through each radiator in succession, through the intervening lengths of pipe, and on around the circuit until it returns to the bottom of the boiler. The radiators are actually sections of the supply main—just as if they were lengths of pipe itself, but fitted with radiating fins. So a minimum of fittings and material are required. But, since the radiators are integral parts of the supply main, no radiator can be shut off. As each radiator is a section of the main circulating system, shutting off any one of them would stop the flow through the entire system. So all radiators heat up and cool off together, as the boiler is turned on and off by the thermostat. Thus, the series loop is suited mainly to compact buildings that do not require room-to-room heating adjustment.

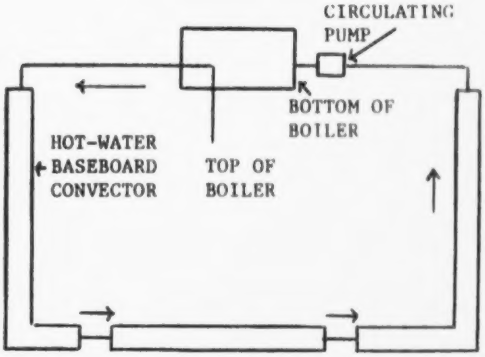

CIRCULATING PUMP
BOTTOM OF BOILER
HOT-WATER BASEBOARD CONVECTOR
TOP OF BOILER

Figure 2-1. Series Loop System

**ONE-PIPE SYSTEM.** The one-pipe system (Figures 2-2 and 2-3) consists of a circuit of pipe leading out of the boiler top and returning to the bottom of the boiler, like the series loop. But the radiators are not an integral part of it. At each radiator location, a branch pipe carries hot water from the circulating main to the radiator inlet. Another branch pipe carries the return water from the radiator outlet back to the circulating main. A shut-off valve at the inlet allows you to regulate the amount of water entering the radiator, or turn it off altogether. If you turn it off, the water simply flows through the main instead of the radiator. A special T-fitting pipe form the radiator connects back into the main circulating pipe. This T has a little scoop facing away from the flow through the main. This causes it to suck water through the radiator when the inlet valve is opened—but it does not block the flow through the main when the valve is closed. The advantage of the one-pipe system, of course, is individual room heating control. But it requires more pipe, more fittings, and more intallation. As it combines central control (as with the series loop) with room adjustment, however, it is a very popular system.

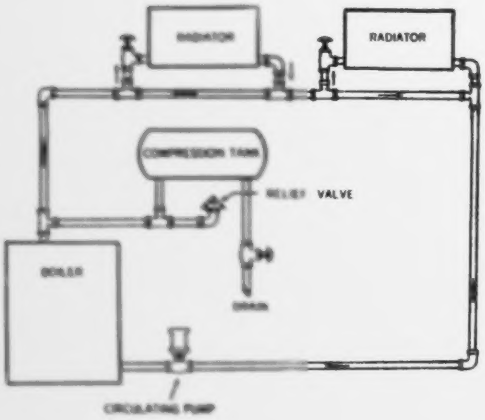

RADIATOR
RADIATOR
COMPRESSION TANK
RELIEF VALVE
BOILER
DRAIN
CIRCULATING PUMP

Figure 2-2. A Diagram of One-Pipe, Closed-Tank, Forced-Circulation Hot-Water Heating System

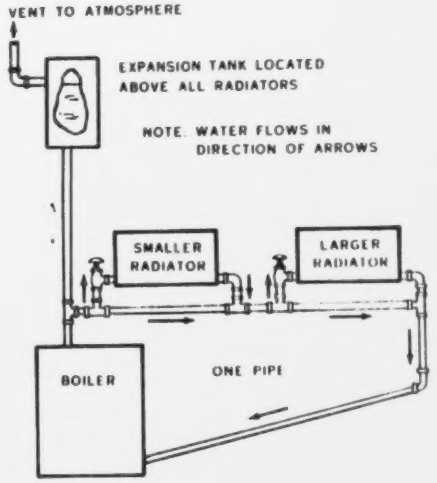

VENT TO ATMOSPHERE
EXPANSION TANK LOCATED ABOVE ALL RADIATORS
NOTE. WATER FLOWS IN DIRECTION OF ARROWS
SMALLER RADIATOR
LARGER RADIATOR
BOILER
ONE PIPE

Figure 2-3. A Diagram of a One-Pipe, Open-Tank, Gravity Hot-Water Distribution System

TWO-PIPE SYSTEM. The two-pipe system (Figures 2-4 and 2-5) has two mains: the supply main feeds water to the risers that serve the heating units; and the return main collects the water returned from those units. The two mains run side by side; the supply main decreases and the return main increases in size where the branches connect. Since the heating units of a two-pipe system are connected parallel, it requires a minimum pumping head. Also, if throttle valves or restricting orifices are used in the risers, the flow through individual units can be adjusted easily over a wide range. However, the two-pipe system requires more pipe and pipe fittings than the one-pipe system. Two-pipe systems are classified as direct-return and reverse-return.

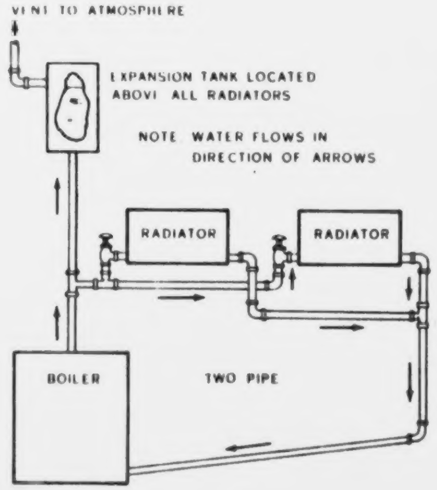

VENT TO ATMOSPHERE
EXPANSION TANK LOCATED ABOVE ALL RADIATORS
NOTE: WATER FLOWS IN DIRECTION OF ARROWS
RADIATOR
RADIATOR
BOILER
TWO PIPE

Figure 2-4. A Diagram of a Two-Pipe, Open-Tank, Gravity Hot-Water Distribution System

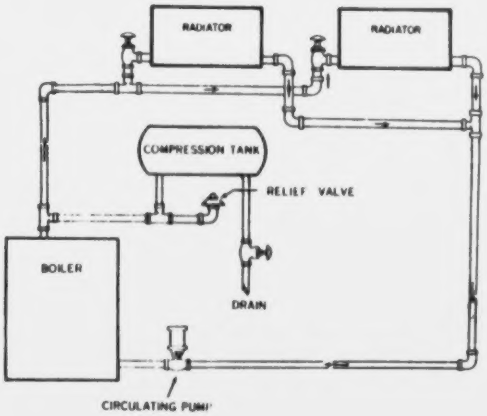

RADIATOR
RADIATOR
COMPRESSION TANK
RELIEF VALVE
BOILER
DRAIN
CIRCULATING PUMP

Figure 2-5. A Diagram of a Two-Pipe, Closed-Tank, Forced Hot-Water Distribution System

Direct Return. The heating units of the two-pipe, direct-return system are parallel. Nevertheless, the water taken from the main to feed the first radiation is returned first; that removed for the second radiator is returned second; and so successfully throughout the heating units. Since this procedure causes a progressively greater friction loss in each additional circuit, the flow circuits become hydraulically unbalanced. This condition may cause the first radiator to have a greater flow than is required to develop its full capacity, while in a large system, the flow through the last unit may be so small that practically no heat is delivered. To balance the system, carefully select pipe sizes to compensate for the differences in length and the consequent friction loss of each circuit. (A balanced system must have the same pressure drop through each piping circuit at design flow rate.) Restricting orifices or throttle valves can also be used to correct flow distribution and to balance a system that is placed in service (see Figure 2-6).

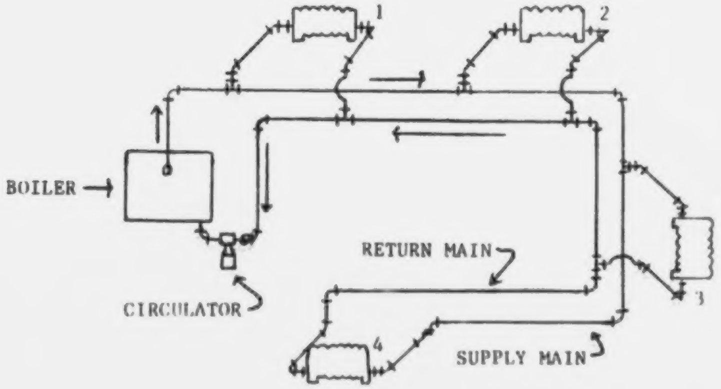


Figure 2-6. Two-Pipe, Direct-Return Systems Are Not Recommended for Residences. Radiators Near the Boiler Can Short-Circuit the Water Supply.

Reversed-Return. In the two-pipe, reversed-return system (Figure 2-7), the water taken from the main to feed the first radiator is returned last to the return main; the water supplied to the last radiator is returned first. As a result, all unit circuits are of approximately equal length, a condition conducive to system balance. The reversed-return system may require more pipe than the direct-return. However, its inherently better flow distribution and natural balance without the aid of additional valves or orifices, compensate for the additional cost, making it the best system to use.

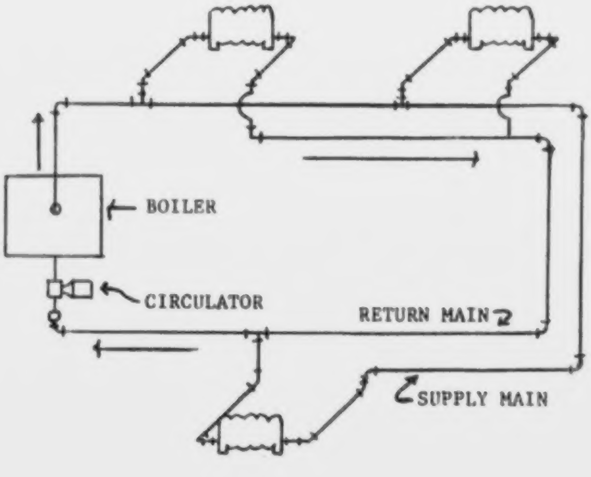


Figure 2-7. A Two-Pipe Reversed-Return System. Flow Through the Supply Main Decreases After Each Branch Connection to a Radiator; Flow Through the Return Main Increases After Each Connection From a Radiator.

### Combined Systems

Because of the different designs of each system a particular installation may combine two or all of the above systems.

## COMPONENTS OF A HOT WATER DISTRIBUTION SYSTEM

### Special Flow Fittings.

Several special tees are available for use in one-pipe systems to deflect main line water into each consumer. These tees impose the necessary pressure drop in the main line between the supply and return riser connections to deflect the quantity of water required to each individual consumer. (Radiator, unit heater, etc.)

### Gate Valves

Gate valves are used in lines where unrestricted flow is important.

### Glove Valves

A globe valve is used to throttle the flow as necessary. These valves are used on the supply line to each consumer to control temperature of an individual room, etc.

### Check Valves

Check valves are used any place in the system where flow reversal could cause damage to the system such as thermal shock. (This is where hot and cold water come together causing a knocking sound.)

### Plug Cocks

The primary function of the plug cock is to adjust the flow rate to control the system temperature. Plug cocks may be used in lines not subjected to excessive heat, but they should be lubricated and tested frequently to insure leak-free operation.

### Anchors, Hangers, and Supports

These devices are used to support and carry the weight of the pipe, valves, fittings, and fluid in a piping system.

### Expansion Joints

In long heating lines, thermal expansion of the pipe is handled easily by expansion joints or loops. By installing these devices into the system the piping has a place to expand. If expansion joints were not installed in long lines the piping could knock down walls or anything that might get in the way of the pipe expanding.

### Strainers

Strainers are installed at various points in the sytem to remove any foreign material that might collect in the lines.

## Air Vents

Air pockets in piping prevent or interfere with circulation. Therefore, all piping must be pitched to vent air into the expansion tank through connection on the radiators or highpoints in the piping system. Mains are pitched up and away form the boiler or heater (in the flow direction) at a slope of 1/4 to 1 inch per 10 feet. Either manual or automatic vents must be installed on radiators, or at high points in the system. If manual vents are used, the air must be vented periodically. Install the minimum number of automatic vents, valves, and fittings as they are points of air entry or water leakage. See Figures 2-9 and 2-10.

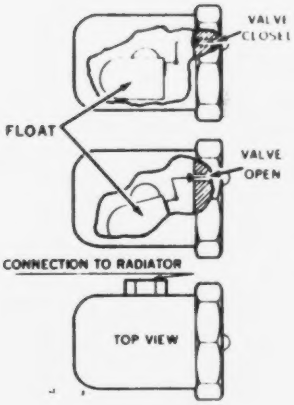
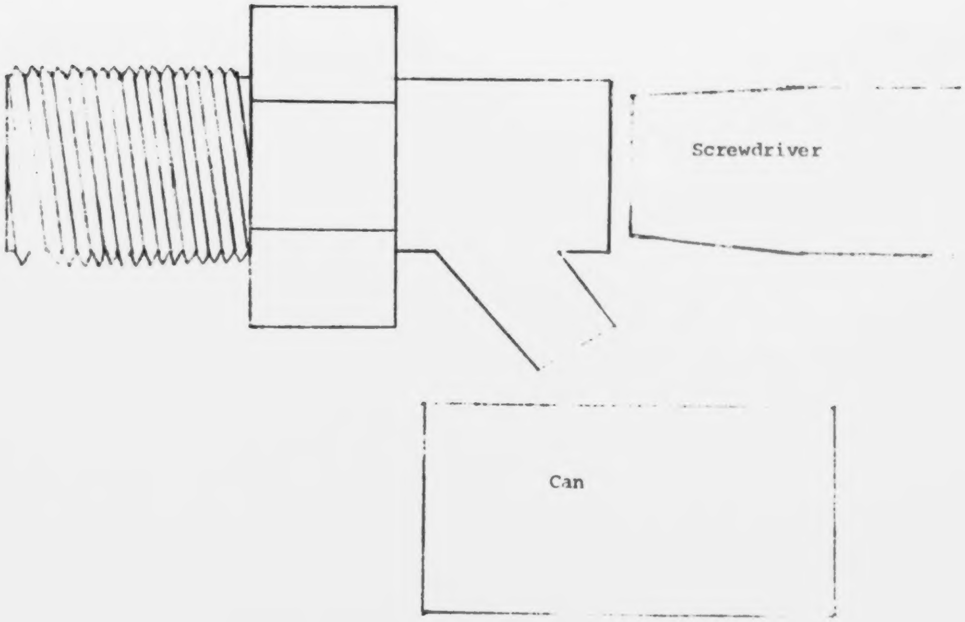


Figure 2-9. One Type of Automatic Air Vent



NOTE: Use screwdriver to open valve. Leave valve open until a steady stream of water goes into can.

Figure 2-10. Manual Air Vent

## FLOW ADJUSTMENT AND BALANCE

A properly designed hot water heating system is, to a large extent self-adjusting. However, most have some way to regulate the water flow and thereby adjust the heat delivery of heating unit and branch circuits during unforeseen conditoins. Flow adjustment and balancing is especially important in two-pipe, direct-return systems because of their inherent hydraulic unbalance. The folloiwng conditions determine the adjusting method used.

### Pipe Size Selection

If the pipe is properly sized, a flow distribution can be established which assures that the pressure drop through each circuit is the same when the system operates at design flow rate. However, since this flow control depends on the pressure drop caused by pipe friction at a certain flow, it may not be adequate for other flow condition.

### Use of Orifices

Orifices can produce friction drops artificially and so balance all circuits for design flow condition. Generally, this method used the same design principles as pipe sizing, except that it creates the required friction drop by introducing an orifice instead of reducing the pipe size.

### Use of Throttle Valves

Throttle valves provide a flexible arrangement for adjusting circuit water flow and balancing the circuit.

### System Balancing

To determine whether hot water systems require balancing, measure the space temperatures with room thermometers, or determine the water temperature drops through heating unit zones with thermometers installed in the piping, or with surface contact thermometers. If the temperature drop method is used, the capacity of the heating units should be adequately matched to the heat load demand.

PROCEDURE FOR SYSTEM BALANCING. To adjust the heat distribution of a hot-water heating system, proceed as follows:

- Prepare a worksheet to record all pertinent information such as: building description, zone, date, equipment data, periodic readings, space temperature readings, and supply and return temperature of heating units or zones.
- To eliminate outside influence, balance the system on an overcase day or at night when heat-gain conditions are minimum. However, the outside temperature should be low enough to require at least 50 percent of the systems heating capacity to maintain the desired inside temperature.
- Place the system in service.
- Open all valves, adjusting elements, dampers for the regulations of air circulation, etc.
- Make sure that no automatic devices that control the flow of water or the capacity of any unit are operating.
- Close all doors or connecting openings between rooms.
- Wait for the system to reach thermal equilibrium, then take a complete set of temperature readings throughout the system. (Thermal equilibrium is obtained when successive temperature readings are approxiamtely the same.)
- Make an initial adjustment of low control devices according to the registered readings obtained in the above step. If adjustment is by space temperature readings, obtain the designed indoor temperature. If the water temperature drop method is used, obtain equal temperature drops through all units or zones.

—— Take a new set of temperature readings, after a new thermal equilibrium has been established throughout the building.

—— Continue adjustments of flow-regulating devices until the desired conditions are obtained.

—— When the system has been satisfactorily adjusted, mark the position of each of the flow-regulating devices (flow cocks, valves, etc.). Then, if the position of the flow-control fittings is disturbed later by accident or during emergency operations, the proper flow to heating units can be reestablished.

## TEMPERATURE CONTROL SYSTEMS

As a rule, more than one thermostat is needed to properly control temperature in large buildings. Better control is obtained by dividing the building into two or more zones, each controlled by a separate thermostat. This practice is called zoning control.

There are many possible zone-control arrangements for hot water heating systems. The following are among the most common.

### Natural Systems

In most natural circulation hot water temperature control systems, the thermostat controls the temperature of the building by controlling the burner. Whenever the temperature in the building falls below the thermostat setting, the thermostat will make the circuit to the burner primary control energizing the burner. When the temperature in the building reaches the thermostat setting, the thermostat will de-energize the burner circuit.

The aquastat on the other hand acts as a limit control shutting down the burner, regardless of the setting of the thermostat, when the water in the boiler reaches a preset temperature.

Suppose the thermostat is set on 68°F and the aquastat is set on 180°F, when the temperature in the building falls below 68°F, the thermostat will start the burner. The burner will run until the water temperature reaches 180°F. The aquastat will then stop the burner. When the water temperature falls below 180°F, the burner will be allowed to start again. This cycle will continue until the thermostat is satisfied.

### Forced Systems Temperature Control

Temperature control systems for forced circulation systems can be classified into two types: single zone and multiple zone systems.

SINGLE-ZONE INSTALLATIONS. In most single-zone temperature control systems, the aquastat controls the burner and the thermostat controls the circulating pump.

The aquastat makes the circuit to the burner primary control whenever the temperature of the water within the boiler falls below the setting of the aquastat. When the water reaches the desired temperature, the aquastat breaks the circuit to the burner.

The temperature of the building is then controlled by a thermostat that will energize the circulating pump when the temperature of the building falls below the thermostat setting.

MUILTIPLE-ZONE INSTALLATIONS. There are many types of temperature control systems used in multiple zone installations. The main difference is in the way the temperature of each zone is being controlled. The thermostat for each zone may control either a circulating pump or a modulating valve.

### Secondary Heating Systems Temperature Control (Indirect Heating)

To control the water temperature of a secondary system you must control the flow of the heating medium. (High temperature water or steam). This is accomplished by the use of a remote bulb.

As the temperature of the secondary water begins to rise the volatile liquid in the bulb beings to gasify. The gas then expands through the capillary tube and begins to exert pressure on the bellows. The bellows begins to expand causing a valve to close off the flow of the heating medium. This causes the water inside the tubes to cool, which in turn allows the secondary water to lower in temperature also. See Figure 2-11.

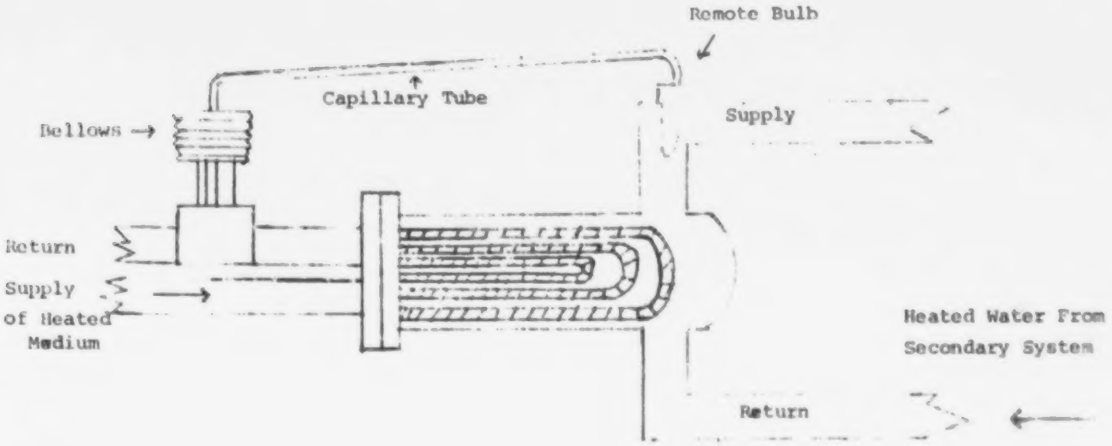


Figure 2-11. Secondary System Temperature Control

## METHODS USED TO TRANSFER HEAT

RADIATORS. The term "radiator" (see Figure 2-12) is usually applied to heat-distributing units composed of cast-iron hollow sections joined by nipples. Three types of radiators are now manufactured: column, small-tube, and wall. In the past, a large-tube radiator was manufactured, but it has been replaced by the small-tube (with a spacing of 1-3/4 inch per section) which occupies less space and can be recessed. Radiators are heated by conduction through contact with steam or hot water. They then transfer the heat to rooms or areas by radiation and convection. Usually, units that have large, exposed heating surfaces emit more radiation heat than those with concealed surfaces. The total amount of heat transferred from the radiator to the surrounding area depends on the heating surface area, the average surface temperature of the unit, the nature and finish of the surface, unit configuration, ambient room temperature, and location of the unit. Locate radiators where the heat loss if greatest, i.e., beneath the windows of a room. If a radiator is placed along an inside wall, cold infiltrated air (which is heavier than warm air) will cross the room near the floor and chill the occupants. But if the radiator is located properly, the infiltering air will be warmed by the radiator and will rise, cross the ceiling, and go down the opposite wall before it contacts the room occupants.

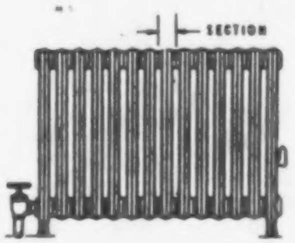


Figure 2-12. Typical Cast-Iron Radiator

In industrial buildings, radiators made of pipe coils are often used. They are usually located under windows or where high rates of heat loss occur. The pipe normally has a diameter of 1, 1-1/4 or 1-1/2 inches. The coils are usually assembled in rows of horizontal pipes and placed vertically on a wall.

CONVECTORS. A convector is a heat-distributing unit which operates by the convection principle. A convector consists of a heating element with an enclosure. Air enters the enclosure through an opening below the heating element and is discharged at another opening above the element. Since the convection principle is used, no mechanical device is required to recirculate the room air through the unit. Cold air enters the convector below the heating element, is heated by contact, and convected upward through the outlet opening of teh enclosure. The types and design of enclosures vary with requirements; outlet air openings are usually grilled; inlet openings can be either open or grilled. Convectors may be freestanding, wall-hung, or recessed.

BASEBOARD UNITS. Baseboard radiation consists of long, low-heating units, generally installed along the bottom of outside walls, which resemble and replace conventional baseboard. They operate by the convection principle, although in most cases, a substantial portion of their total heat output is transferred by direct radiation to cooler surfaces. Baseboard units are suitable for use on hot water and steam heating systems. These are their main advantages.

- Ease of installation along cold walls and under areas where rate of heat loss is greatest.
- Heat distribution near the floor and, consequently, a more uniform temperature from floor to ceiling.
- Practically no interference with furniture.
- Ease of concealment.
- Convenience of installation (to prevent cold floors) in houses without basements.
- Perimeter heating and even wall-to-wall temperatures.

Baseboard units may be of three basic types: radiant-type, radiant-convector and finned-tube.

Radiant-Type. Radiant-type units are usually constructed of hollow cast-iron or steel sections. When no space is available for floor or wall-mounting, they are suspended from ceilings. However, suspended units transfer less heat by convection than do floor or wall units.

Radiant-Convector. Radiant-convector units have enclosures with air inlets at the bottom and air outlets at the top. In some designs, the openings have grills or dampers to regulate the airflow. The heating elements consist of hollow cast-iron or steel sections. A large percentage of the heat output of these units is transmitted by convection. Although the temperature of all baseboard units is kept rather low, they can yield a higher heat output per linear foot than the radiant type. They are, therefore, particularly suitable for installation with high heat loss or scarce wall space.

Finned-Tube. The heating elements of finned-tube baseboard units consist of tubes into which lightweight fins are mechanically bonded or embedded to increase the heating surface. The tubes may be ferrous or nonferrous (usually steel or copper) with fins of steel or aluminum. The units come in standard lengths for ease of installation. The heating elements are concealed by enclosures of several designs, and a considerable percentage of the total heat output is emitted by convection. The heat output per linear foot varies with the different designs, sizes and materials used. In general, baseboard installations are designed for the minimum output per linear foot compatible with the total heat losses. Units are usually installed along as much of the exposed wall as possible. When desired, dummy sections without heating elements can be used to provide continuity in the installation and simulate a conventional baseboard.

FINNED TUBE UNITS. When maximum covected heat per linear foot is required, finned tube units are normally used. They consist of finned-tube elements fabricated by bonding metallic fins to metallic tubes. The tubes and fins can be all steel, or copper (tubes) and aluminum (fins). Generally, these units are placed along the walls, where the heat loss is greatest; if necessary, they can be installed in two-or three-tiers. The heating medium is either steam or hot water. When hot water is used in the multiple tier installation, a continuous water flow through a coil-type arrangement is preferred. If a grid installation, with header connections for parallel flow, is used, water may short-circuit through the path of least resistance and reduce the heat output. These units can be equipped with various types of covers, enclosures or protective grilles. However, they are often installed without covers, and with the elements supported from walls or ceiling by suitable hangers. The heating output of finned tubes depends on operating conditions, heating surface, and fin design construction materials, surface finish. In most cases, a substantial percentage of the heat is transferred by convection.

PANEL HEATING. Low temperature hot water is the most frequently used heating medium. Heating is supplied by circulating the hot water through embedded piping or tubing. The most common type of panel heating are ceiling, wall and floor.

UNIT HEATERS. The unit heater consists of a factory-made assembly. Its basic elements are a fan and motor, a heating element, a casing, and outlet vanes or diffusers.

Hot water unit heaters are chiefly used to heat large, unpartitioned areas of commercial structures, such as garages, shops laboratories, stores, base exchanges, and mess halls.

## SUMMARY

Hot water heating systems operate the same as the boilers do. They direct the heated water by either natural or forced circulation.

There are four basic types of hot water systems, the series loop, the one-pipe system and the two-pipe systems, direct and reverse return.

In a series loop system the consumers are part of the supply main. If you shut one off they all go off.

In the one-pipe system the consumers are not part of the supply main. To help direct the flow of water through the circuit are special flow fittings. These are "scoops" that direct the flow of water through each consumer.

There are two types of two-pipe systems, the direct return and the reverse return. In a direct return the first consumer to receive the heated water is also the first one to return the water. This causes the last consumers to be "robbed" of the heater water.

In the reverse return the first consumer to receive the heated water is the last to return it. This type of system is the easiest to balance.

Balancing a hot water system can be accomplished by changing the size of the pipe, by using orifices or by using throttle valves.

Temperature control of hot water systems is done by zoning. This helps to break it down into smaller areas, thereby making temperature control much easier. This is done by either single or multiple zones.

QUESTIONS

1. What are hot water consumers?

2. What type of piping system is easiest to balance?

3. What is added to a one-pipe system to help direct the flow of water to the consumers?

4. What is the purpose of expansion joints?

REFERENCES

1. AFM 85-12, Volume I, Operation and Maintenance of Central Heating Plants and Distribution Systems

2. AFM 85-12, Volume II, Operation and Maintenance of Space Heating Equipment and Process Heat Utilization

# TROUBLESHOOTING HOT WATER SYSTEMS

## OBJECTIVES

Using information given, explain the procedures to follow in troubleshooting a hot water heating system by correctly answering 12 out of 15 questions.

Using information given, explain how to inspect and replace aquastats, maintenance of pressure regulators, precedures to follow to inspect and maintain special flow fittings, installation of air bleed valves and pressure regulators, procedures used to balance system and inspecting boilers for leaks, corrosion, and scale by correctly answering sixteen out of twenty questions.

## INTRODUCTION

Operating a hot water heating system consists of more than just heating water. There are many things that must be done to make sure that everything works just the way it is supposed to.

Suppose you set your hot water system up, started it up, and it wouldn't work. What would you do? This section deals with the procedures to follow in troubleshooting.

## INFORMATION

## PROCEDURES USED TO TROUBLESHOOT FIRESIDE

In order to more easily understand how to troubleshoot a hot water heating system, we will break it down into three areas: The fireside, the waterside and the piping system.

### Fireside

The fireside of the hot water boiler is the area where the fuel is burned to produce heat. When you troubleshoot the fireside you will look at the fuel, the burner, controls, combustion chamber and finally the exhaust passageways.

### Burners

Let us say, for instance, that your burner was not operating correctly, what would you check? First, you have to look at the type of fuel you are using.

### Coal

Suppose you were firing with coal and you noticed that your fire was not burning properly. You first have to determine what is causing the problem. Is it because you have too much fuel, too little fuel, or is it because of improper combustion?

If it was because of too much fuel you would have to adjust your controls to slow down your coal feed rate. If it was because of too little fuel then you would have to adjust your controls to speed up your coal feed rate. However, if it was caused by improper combustion then you would have to adjust your air supply accordingly.

Any additional problems encountered, you should refer to the manufacturer's instructions.

### Oil

When you are operating with oil as your fuel supply, then you have a few more items to think about when troubleshooting. Not only do you to think about your fuel supply and controls, you also have to look at whether it is in your ignition system or oil piping system.

Once again, before you begin to troubleshoot, you first have to determine what is causing the problem by where it exists.

In most cases if the problem exists in the ignition system, your burner will puff upon startup. This is caused by a weak ignition. In order to find out what is causing it you will have to look at your electrode setting, transformer porcelain or electrodes and connections.

Problems enocuntered in your control system were covered previously when you covered oil burners. Refer to the troubleshooting guide under oil burners or manufacturer's instructions.

Gas

Troubleshooting a system that is firing with gas is probably the easiest of all the fuels. Much of the time the problems encountered with gas-fired equipment is related to the pilot light. It can be caused by an improperly adjusted flame, bad thermocouple or bad power unit (electromagnet used to hold valve or contacts open).

As with oil, troubleshooting a gas control system was covered previously. Any further problems encountered, you should refer to the manufacturer's instructions.

## PROCEDURES USED TO TROUBLESHOOT WATERSIDE

Waterside

The waterside of a hot water boiler is the inside of the boiler. This includes not only the boiler itself, but also the circulating pump.

Tube failure

One type of trouble encountered with hot water boilers is a tube failure. This type of problem is encountered only on steel boilers because cast iron boilers do not have tubes, they have sections.

Tube failure can be caused by a couple of things. One is by corrosion. This is where the impurities in the water build up inside the boiler causing scale. Over a period of time this can begin to restrict water flow. This in turn causes more heat to build up in this one spot or area. After a period of time the tube will begin to bend and eventually fail. By the time this happens it is time to either overhaul or replace the boiler.

Valves

Whenever you are troubleshooting it is good practice to check all valves to make sure that the ones that are supposed to be open are open and the ones closed are closed.

Leaks

Anytime a fluid such as water is run through a piping system there is always a possibility of leaks. Boilers are no exception.

Leaks on a hot water boiler can occur either inside the boiler or outside. Whenever there is a leak on a boiler or system there will be a drop in pressure, in a closed system, and a drop in the water level in the expansion tank.

Pumps

The types of problems encountered with circulating pumps are either leaking seals, worn out impellers, broken couplings or burned out motors.

Whenever the seals begin to leak they must be replaced as soon as possible. If they are not there is a possibility of water entering the motor and burning it out.

Seal replacement is a fairly easy process, depending on the pump manufacturer. Many use what is called a mechanical seal. This type of seal uses a spring to push the seal towards the shaft. After a period of time the seal wears to a point where it is much larger than the shaft itself. When this happens, the spring can no longer keep enough pressure to prevent water from coming out by the seal. At this point replacement is a necessity.

Many domestic hot water boilers use a circulating pump with a spring-type coupling. After many months in operation and starting and stopping, the springs will wear holes in the coupling. When this happens the coupling must be replaced before any further damage is done.

If the impeller begins to wear out the output of water from the pump will decrease considerable. Replace the impeller by following the manufacturer's instructions for that particular pump.

Whenever it is necessary to replace the pump motor it is good practice to check the old motor for lack of lubrication or over lubrication.

## PROCEDURES USED TO TROUBLESHOOT SYSTEM

### System

What is meant by a hot water system is the piping itself, such as the one-pipe or two-pipe system.

### Loss of System Pressure

Whenever there is a loss of system pressure you must check to find out why it is dropping. First, you should check the expansion tank to see if you have lost the air cushion. You can tell by looking at the gauge glass on the tank. A high water level would indicate a loss of the air cushion.

In order to replace the cushion you must drain the water from the tank while opening the vent on the airtrol. Once the tank is emptied, close the drain and the airtrol and refill the tank. Watch the tank to see if you lose the air cushion again. If you do you will have to look for a leak on the air cushion side of the tank.

Another component that could allow you to lose system pressure is a pressure regulator. Possibly it could be out of adjustment. If it is, readjust and watch the system to be sure it is working correctly. It it is defective it must be replaced.

Finally check to make sure that the correct valves are open or closed and also that there is no unwanted air in the system.

## PROCEDURES USED TO INSPECT AND REPLACE AQUASTATS

### Inspection

Inspection of an aquastat consists of checking the installation and adjustment. Since installation was covered earlier, this section will deal with the adjustment procedures.

The only adjustment made on an aquastat is setting the range dial for the desired operating temperature, although in some cases, you can also adjust the differential. The differential may be fixed (factory set) or adjustable. Adjustable differentials may be adjusted over a wide range (2 to 45°F in some cases) by turning a knob or a slotted screw. The differential determines the temperature lag of the firing equipment between stop and start. To determine the point at which a burner will restart, subtract the differential setting from the range setting.

### Replacement

When an aquastat fails or does not maintain the boiler temperature within a tolerable range, it shuld be replaced. The removal of an aquastat is relatively simple and normally consists of loosening one or two screws and removing the aquastat and element from the boiler. Physical replacement of an aquastat is equally easy, however, make certain the replacement aquastat has the same range as the old one. After the aquastat is replaced, adjust in accordance with the preceding paragraph.

## PRESSURE REGULATOR MAINTENANCE PROCEDURES

The most common types of problems you will encounter when using a water pressure regulating valve are the following:

____ Relief valve drips cannot be shut off tightly.

____ Boiler pressure rises above the reducing valve setting.

____ Water escaping "seep hole" on top of the regulator.

____ Water escaping feeder side of the combination valve.

Some of the problems listed above (particularly the first two) may not be the fault of the valve itself. For example, a dripping relief valve can be caused by either an expansion tank being completely filled with water, an undersized expansion tank, or a leak in the coil of a tankless or indirect water heater installed in the boiler. These possibilities should be checked before attempting to service or repair the valve.

If, by process of elimination, the problem can be traced to the valve, try tapping the side of the valve with a wrench. Sometimes a piece of foreign matter will become lodged and cause the regulator piston to stick. A sharp tap with a wrench may dislodge it and allow the valve to function properly.

Foreign matter, such as dirt or pipe scale, will often cause a valve to malfunction by lodging on a seating surface or nicking or chipping the surface. Valve manufacturers will often provide replacements or instructions for field servicing and repairing.

Water seeping from the regulator "seep hole" or from the feeder side of a combination valve is usually an indication that there is a rupture or leak in the diaphragm. Follow the procedures described in the preceding paragraph for repairing the valve. An occasional flushing of the relief side of the combination valve will reduce the possibility of the type of lime or scale buildup that can cuase the valve to fuse shut.

## INSTALLATION PROCEDURES FOR AIR BLEED VALVES AND PRESSURE REGULATORS

### Pressure Regulators

You should install this valve at approximately the same level as the top of the boiler. Figure 3-1 shows the typical location of a water pressure regulating valve. Before installing the valve, flush out the supply pipe to clear it of scale, dirt, and other foreign matter that could disrupt its operation. Install a shutoff valve ahead of the regulator and then connect the supply line to the inlet. The inlet side of the water pressure regulator valve is usually marked "IN" on the valve casting.

To fill the system, open the shutoff valve located ahead of the pressure regulating valve. Water will flow into the system until it is full and under pressure. The shutoff valve must always be kept open when the system is in operation.

For a building in which the factory pressure setting may not be sufficient to lift the water to the higherst radiator, it may be necessary to reset the regulating valve for a higher pressure. To do this, calculate the number of feet from the regulator to the top of the highest radiator. Divide this by the number of feet equal to one pound of water pressure. One pound of water pressure is equal to 2.31 feet. In other words, if a system is 45 feet high, the necessary pressure can be determined by 45 divided by 2.31 = 19.48 psig. Therefore, to assure water at the highest point of the system, a boiler pressure of 19.5 psig is necessary.

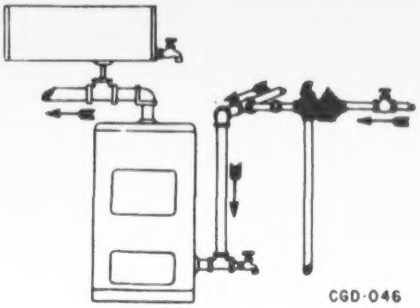


Figure 3-1. Typical Location of Pressure Regulating Valve

Air Bleed Valves (Air vents)

Inspection of air bleed valves consist of visually examining for signs of leakage or checking to see if they work properly. If an air bleed valve fails, replace it.

## INSPECTION AND MAINTENANCE PROCEDURES FOR SPECIAL FLOW FITTINGS

Inspection

Inspection of special flow fittings is accomplished by measuring the temperature drop of the water through the consumer. If there is a noticeable decrease in temperature from the rest of the consumers it indicates a possibly defective flow fitting.

Maintenance

In order to perform maintenance of a special flow fitting the piping system must be dissassembled. Once apart, inspect for scale, corrosion or mission "scoop". If scale has built up on the fitting, clean and replace. If it is corroding or worn away it must be replaced.

## PROCEDURES USED TO BALANCE SYSTEM

System Balancing

To determine whether hot water systems require balancing, measure the space temperatures with room thermometers, or determine the water temperature drops through heating unit zones with thermometers installed in the piping, or with surface contact thermometers. If the temperature drop method is used, the capacity of the heating units should be adequately matched to the heat load demand. To adjust the heat distribution of a hot water heating system, proceed as follows:

—— Prepare a worksheet to record all pertinent information, such as building description, zone, date, equipment data, periodic readings, space temperature readings, and the supply and return temperature of heating units or zones.

—— To eliminate outside influence, balance the system on an overcast day or at night when heat-gain conditions are minimum. However, the outside temperature should be low enough to require at least 50 percent of the system's heating capacity to maintain the desired inside temperature.

—— Place the system in service.

—— Open all valves, adjusting elements, dampers for the regulation of air circulation, and other such items.

—— Make sure that no automatic devices that control the flow of water or the capacity of any unit are operating.

—— Close all doors or connecting openings between rooms.

—— Wait for the system to reach thermal equilibrium; then take a complete set of temperature readings throughout the system. (Thermal equilibrium is obtained when successive temperature readings are approximately the same.)

—— Make an initial adjustment of flow control devices in accordance with the registered readings obtained. If adjustment is by space temperature readings, obtain the designed indoor temperature. If the water temperature drop method is used, obtain equal temperature drops through all units or zones.

—— Take a new set of temperature readings after a new thermal equilibrium has been established throughout the building.

—— Continue adjustments of flow regulating devices until the desired conditions are obtained.

—— When the system has been satisfactorily adjusted, mark the position of each of the flow-regulating devices (flow cocks, valves, and other devices). Then, if the position of the flow-control fittings is disturbed later by accident or during emergency operations, the proper flow to heating units can be reestablished.

## INSPECTING BOILERS FOR LEAKS, CORROSION AND SCALE

Once a year a hot water boiler should be opened up and inspected for signs of leaks, corrosion and scale.

Leaks in a hot water boiler are usually easy to spot. If they are on the external surfaces they will show up as scale buildup where the water is coming out (much like wax dripping off a candle). Usually leaks occur where there are joints, such as at threaded connections or flanges.

If these leaks have been going on for a period of time the water coming through will corrode the pipe. When this happens, the pipe or fitting must be replaced.

## SUMMARY

In order to troubleshoot a hot water heating system you must first break it down into three areas. They are the fireside, waterside and system.

When looking at the fireside you are checking the area where the fuel is burned to produce heat. Start first by looking at the type of fuel you are burning such as; coal, oil or gas. This is necessary because each will have different troubles.

Next, you must check the waterside. This is the part where the water is stored. Some of the things that could cause troubles are tube failures, valves (open or closed), leaks (internal and external), and pumps.

Last you would have to troubleshoot the system. This includes the piping and its accessories. Probably the biggest problem with the system is loss of system pressure. Without the proper pressure the highest consumers might not get heated.

As with any system you must periodically check the components to make sure they are working properly. You should check the aquastat, pressure regulator, air bleed valves, and special flow fittings. If they are all working properly then you must balance the system to make sure you are getting even heat distribution.

QUESTIONS

1. What areas is troubleshooting a hot water heating system broken down to?

2. When replacing a pump motor, what should you check?

3. An aquastat fails to maintain the proper temperature, what should you do?

4. What should you check before attempting to service or repair a pressure regulator?

REFERENCE

1. AFM 85-12, Volume I, Operation and Maintenance of Central Heating Plants and Distribution Systems

2. AFM 85-12, Volume II, Operation and Maintenance of Space Heating Equipment and Process Heat Utilization

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

# OPERATION AND MAINTENANCE OF HOT WATER SYSTEMS

## OBJECTIVES

Using information given, remove a boiler from service, drain, flush and fill boiler with instructor assistance.

Using information given, inspect boiler for leaks, inspect and replace aquastats, and maintain pressure regulators with instructor assistance.

Using information given, inspect for corrosion and scale and troubleshoot hot water heating system with instructor assistance.

## INTRODUCTION

The information required for this unit of instruction has been covered in the previous three units. The procedures and instructions required in this unit are contained in workbook J3ABR54532 001-V-4, Operation and Maintenance of Hot Water Systems.

## INFORMATION

See SGs V-1, V-2, V-3 for this information. The workbook will be used in this unit.

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

SG J3ABR54532 001-V-5

# SOLDERING AND WELDING

## OBJECTIVES

Given information, explain basic facts about the types and sizes of copper tube and fittings by correctly answering 80% of questions.

Given handtools, copper tubing kit, copper tubing and instructions, measure, cut, bend, swage, and flare the copper tubing with a maximum of two instructor assists.

Given handtools, sandpaper, steelwool, hydrocarbon torch and assortment of fittings, use proper techniques to soft solder two copper tubing joints with a maximum of two instructor assists.

Given information, identify the theory of oxyacetylene welding and related equipment by answering 80% of the questions.

Given handtools, copper tubing, oxyacetylene equipment, sil-phos and flux, use proper techniques to hard solder two copper tubing joints with a maximum of two instructor assists.

Given handtools, metal, oxyacetylene equipment, and sandpaper, use proper techniques to weld two pieces of metal together with at least 80% weld penetration with a maximum of two instructor assists.

## INTRODUCTION

The use of copper tubing has become very popular and is quite rapidly replacing iron pipe in modern heating installations. Due to its light weight, the tubing is easily transported and can be quickly installed. The joints are quick and easy to make and are as permanent as the tubing itself. All pipes do not offer the same resistance to the flow of liquid going through them nor are they subject to the same amount of corrosion. Copper tubing has the least resistance to liquid flow or corrosion and will last longer than steel or iron pipe. Since the flow of liquids is comparatively free, copper tubing can be smaller than iron pipe and still deliver an equal amount of liquid to the point of discharge.

Copper tubing is also recommended for a wide range of domestic, commercial, industrial and special purpose installations. They are economical because of their long life, low friction loss to liquid flow and high tensile strength to withstand pressure or stress. They are also easy to join together by using flared connections or by soft soldering. While this information is very true, the initial cost is high and for that reason it is not used for general purposes. Some of the most important information on the use of copper tubing in heating systems is presented in the following main headings of this text.

——— Types of Copper Tubing and Fittings

——— Bending, Flaring and Swaging

——— Types of Solder

——— Operation of the Hydrocarbon Torch

——— Procedures for Soldering

Welding or brazing two pieces of metal together into one piece is becoming popular, when the parts are to be more or less a permanent installation. Some of the most important information on the use of welding or brazing equipment in heating systems is presented under the following main headings.

- Oxyacetylene Combustion
- Oxyacetylene Equipment
- Safety Precautions When Using Oxyacetylene Equipment
- Procedures for Silver Soldering
- Procedures for Welding

## INFORMATION

## TYPES OF COPPER TUBING AND FITTINGS

### Identification of Copper Tubing

There are four main types of copper tubing and pipe; they are K, L, M and DWV. The classification is determined by wall thickness. Copper pipe or tubing is measured by outside diameter (OD).

TYPE K. A green color band, in addition to stencil on the pipe surface, identifies the pipe as type K. It is recommended for underground installation and high pressure. Type K is available in a variety of sizes ranging from 1/4" to 12" in diameter and has the thickest wall of the four types.

TYPE L. A blue color band identifies this copper tubing. It has a medium wall thickness and is recommended for interior use. Type L is also available in 1/4" to 12" diameters.

TYPE M. Type M has a light wall thickenss and is used in low-pressure installations. It is color-coded red in the copper color code system. Type M is available in sizes 1/4" through 6" in diameter.

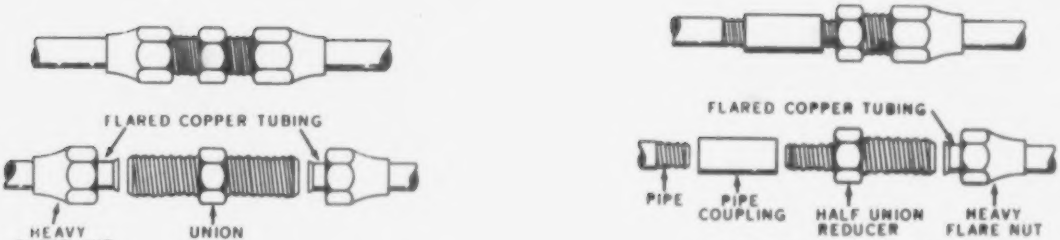
TYPE DWV (DRAIN, WASTE AND VENT). The thinnest wall of all types of copper tubing is classified as DWV. It is used in non-pressure applications and is distinguished by a yellow band. This material is available in sizes 1/4" to 6" in diamter.

Copper pipe and tubing may be obtained either in hard drawn (hard temper) or annealed (soft temper).

The hard-drawn copper (K, L and M) is available in 20-foot lengths. Annealed copper, including K, L and DWV, is available in rolls.

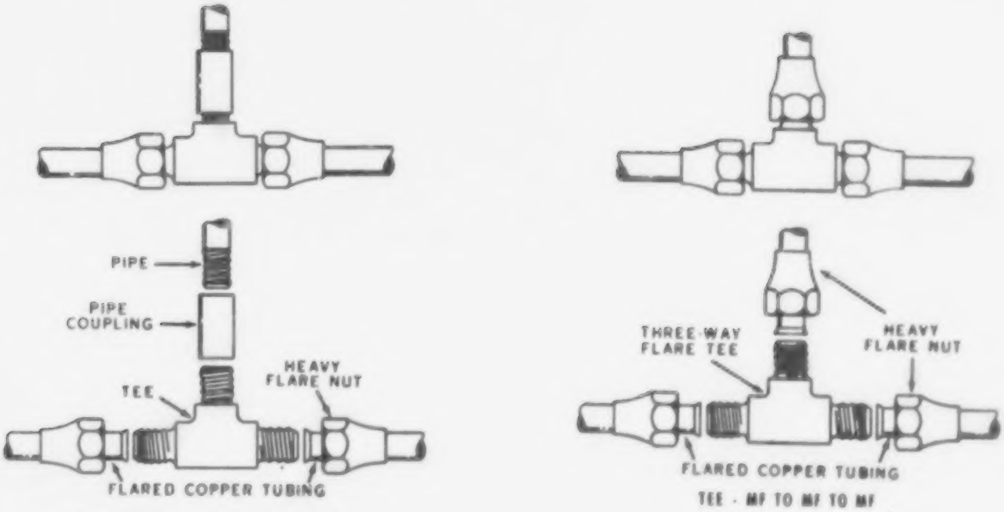
### Copper Fittings

There are two types of screwed copper connections. The use of compression ring (ferrule) that forms a seal when the nut is tightened is one example. Other types of screw fittings for copper connections are the flare fittings, illustrated in Figure 5-1.


FLARED COPPER TUBING
HEAVY FLARE NUT
UNION
FLARED COPPER TUBING
PIPE
PIPE COUPLING
HALF UNION REDUCER
HEAVY FLARE NUT

UNION - MF TO MF

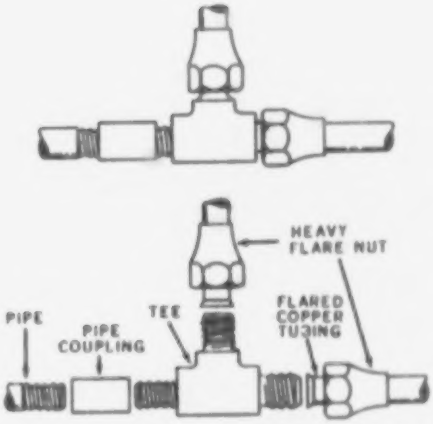
HALF UNION REDUCER - MF TO MPT


PIPE
PIPE COUPLING
TEE
HEAVY FLARE NUT
FLARED COPPER TUBING
THREE-WAY FLARE TEE
HEAVY FLARE NUT
FLARED COPPER TUBING

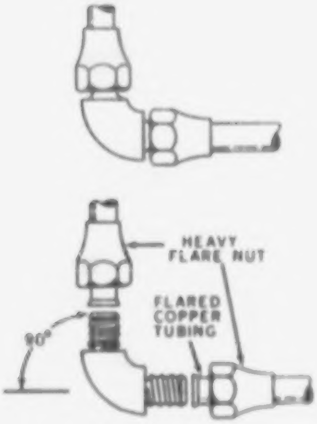
TEE REDUCER - MF TO MF TO MPT

TEE - MF TO MF TO MF

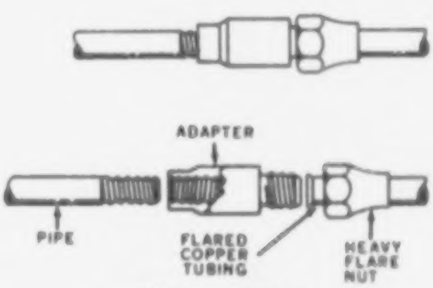
Figure 5-1. Copper Fittings


HEAVY FLARE NUT
PIPE
PIPE COUPLING
TEE
FLARED COPPER TUBING

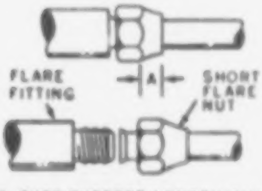
TEE - MF TO MPT TO MF


HEAVY FLARE NUT
FLARED COPPER TUBING
90°

90° ELBOW - MF TO MF


ADAPTER
PIPE
FLARED COPPER TUBING
HEAVY FLARE NUT

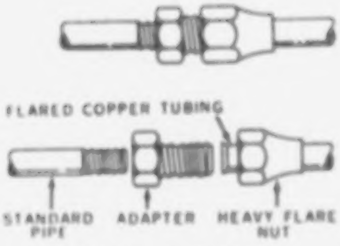
ADAPTER - MF TO FPT


FLARE FITTING
A
SHORT FLARE NUT

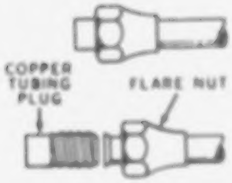
NOTE: TUBE-SUPPORT LENGTH (A) IS SHORT TO PREVENT WATER FROM COLLECTING AND FREEZING. USE OF THIS NUT IS RECOM[illegible]D WHERE FROSTING AND DE[illegible] OCCUR

SHORT FL[illegible]

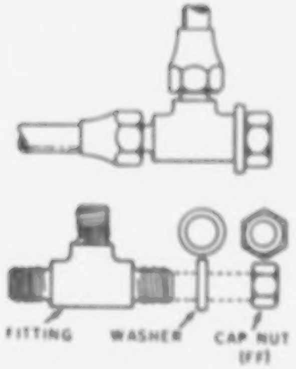
Figure 5-1. Copper Fittings (Continued)

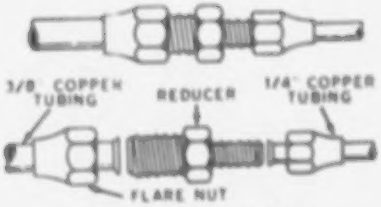

FLARED COPPER TUBING
STANDARD PIPE
ADAPTER
HEAVY FLARE NUT

ADAPTER - MF TO FPT

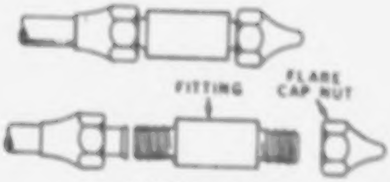

COPPER TUBING PLUG
FLARE NUT

PLUG - MF


FITTING
WASHER
CAP NUT (FF)

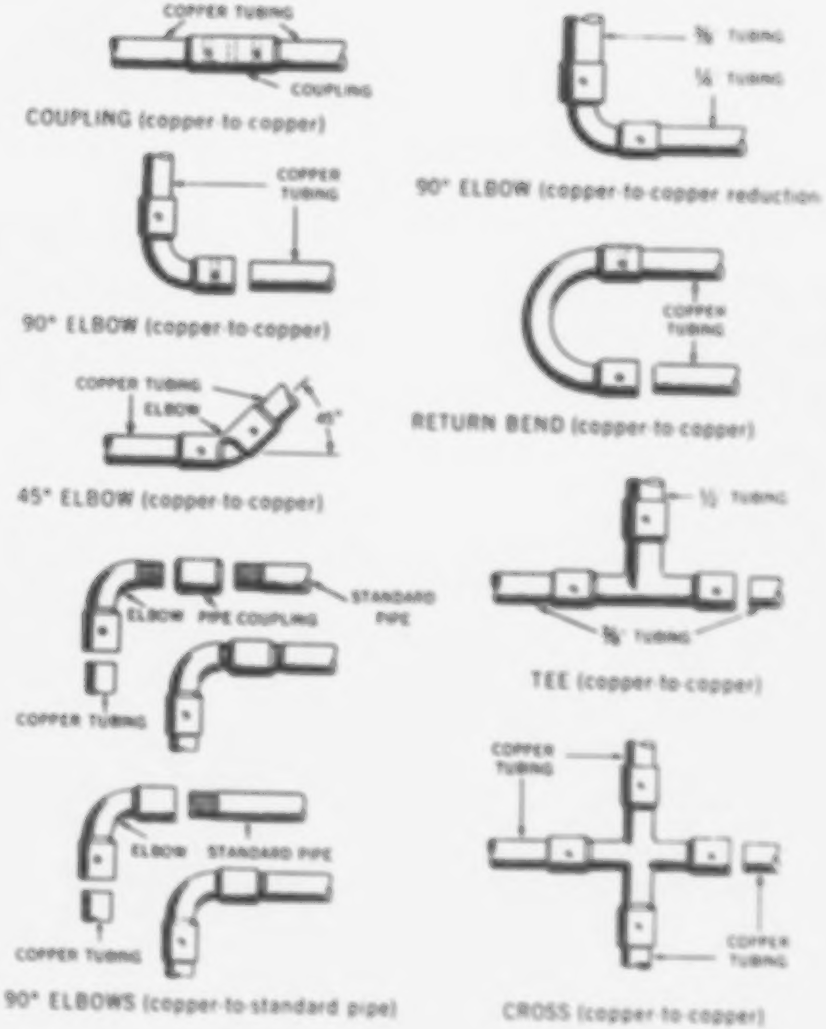

3/8" COPPER TUBING
REDUCER
1/4" COPPER TUBING
FLARE NUT

UNION REDUCER - MF TO MF


FITTING
FLARE CAP NUT

FLARING NUT CAPS

Figure 5-1. Copper Fittings (Continued)


COPPER TUBING
COUPLING
5/8 TUBING
1/2 TUBING
COPPER TUBING
COPPER TUBING
COPPER TUBING
ELBOW
45°
1/2 TUBING
ELBOW
PIPE
COUPLING
STANDARD PIPE
5/8 TUBING
COPPER TUBING
COPPER TUBING
ELBOW
STANDARD PIPE
COPPER TUBING
COPPER TUBING

COUPLING (copper-to-copper)

90° ELBOW (copper-to-copper reduction

90° ELBOW (copper-to-copper)

RETURN BEND (copper-to-copper)

45° ELBOW (copper-to-copper)

TEE (copper-to-copper)

90° ELBOWS (copper-to-standard pipe)

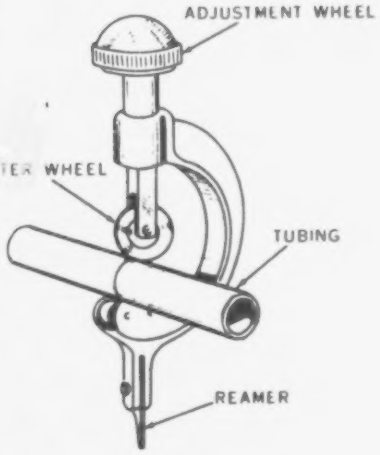
CROSS (copper-to-copper)

Figure 5-1. Copper Fittings (Continued)

## Cutting Copper Tubing

Copper tubing is measured in length the same as pipe: end-to-end when no fittings are used, end-to-center when one fitting is used and center-to-center when a fitting is used on both ends.

What makes this connection a perfectly airtight and watertight joint? The answer lies in the correct preparation of the tubing. To prepare the watertight joint, measure and cut the tubing to length. Allow 1/8 to 1/4 inch for loss of flare. The desired type of tool for cutting the tubing is a tube cutter, see Figure 5-2, but a fine-toothed hacksaw (32 teeth to an inch) may be used if a properly designed jig is available, see Figure 5-3. After the tubing is cut, it is restored to its original inside diameter by using the reamer attached to the tube cutter, see Figure 5-2, for a half-round file if a reamer is not available. If there are any rough marks or scratches on the outside of the tubing, they can be removed with steel wool or emery cloth.



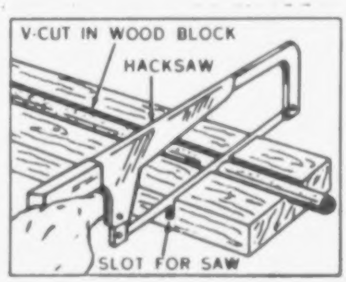


Figure 5-3. Jig for Cutting Tubing

Figure 5-2. Tube Cutter and Reamer

Preparing of the flare on the tubing can be done either with a flare block or with a plug-type flaring tool. Either procedure is satisfactory in making a good joint.

## Bending Copper Tubing

Copper tubing used for liquid lines is soft enough to be formed into desired bends where it is necessary to change direction of a line. If care is taken copper tubing may be bent by hand, but the slightest excess pressure at one particular point will result in a flattened or kinked tube, rendering it useless. Hard tubing requires annealing (softening) the portions to be bent. This can be done by heating the portion of tubing to a dull red with a blowtorch. Applying cold, soaked rags to the heated portion helps annealing and cools the metal quickly.

BENDING BLOCK. One method used in bending soft copper tubing is the use of a bending block of correct size. The block is mounted on a table or other solid structure with a metal loop attached to the edge of the table. The end of the tube is inserted in the loop, and using both hands, the tubing is gradually formed over the contour of the block. (See Figure 5-4.)

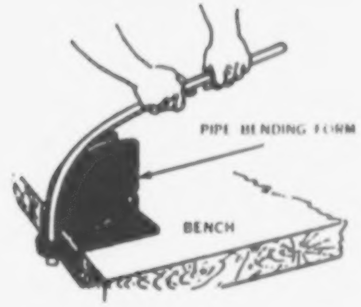


Figure 5-4. Bending Tubing Over Block

**SAND METHOD.** Often kinking is prevented when bending soft copper tubing by filling the tubing with sand. The sand in the tubing keeps the walls from collapsing during the bending process. (See Figure 5-6.).

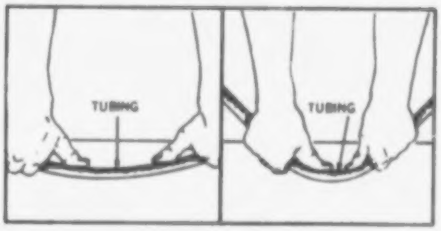


Figure 5-6. Bending Tubing Filled with Sand

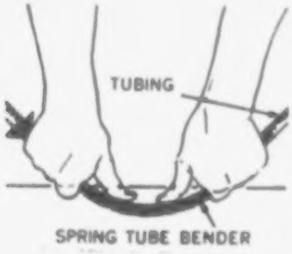


Figure 5-7. Bending Tubing Using a Spring

**SPRING BENDER.** Still another method that is used by the heating specialist to bend soft copper tubing without buckling it so easily is to place the correct size flexible bending spring over the tubing and gradually form it with the thumbs and at the same time pressing the tubing against a table or solid flat structure. (See Figure 5-7.)

**MECHANICAL TUBE BENDER.** Mechanical tube benders are considered the most practical way to bend copper tubing. They are made in many sizes and designs. Figure 38 illustrates a tube bender and the steps used in bending tubing. When placing the tubing in the bender, raise the right handle of the bender as far as it will go so that it rests in a horizontal position. Raise the clip and drop the tubing in the space between the handle slide block and the bending form. (Drop clip over the tube and turn handle slide bar around the pin and press to the right.) Note that ZERO mark on bending form will line up with the mark on the slide bar. Proceed to bend to the desired angle. (See Figure 5-8.)

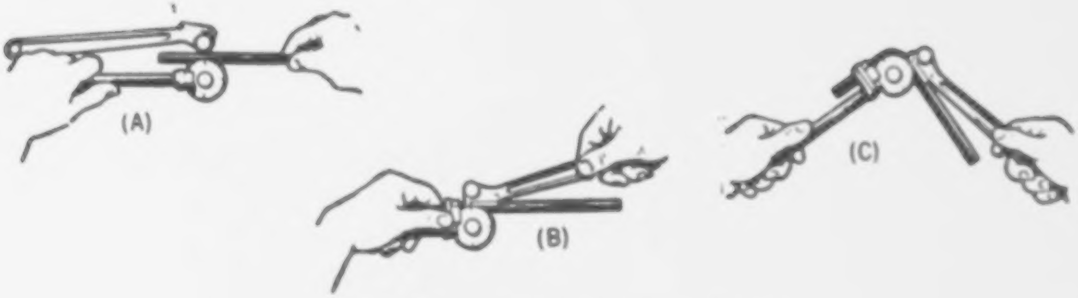


Figure 5-8. Bending Copper Tubing

You can bend tubing to any angle up to 180° with this tube bender. To remove the bent tube from the bender, lift the handle slide bar back to its horizontal position, raise the clip, and remove tube from bender.

Expansion Loops

Expansion loops are needed to take up shock from vibration or changes of pressure to temperatures. The loops can be shaped to withstand these changes. Figure 39 shows two examples of expansion loops made by tube benders.

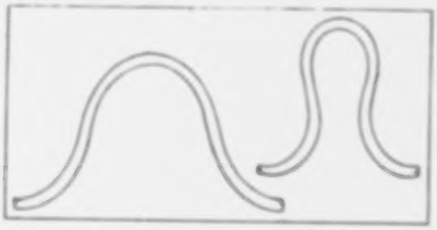


Figure 5-9. Expansion Loops

Flaring Copper Tubing

An easy and satisfactory method of joining copper tubing is done by flaring the ends of the tubing and pressing the flared end against the tapered surface in the fitting and then screwing the flare nut up tight over the end of the fitting. (See Figure 5-10.)

An advantage of this type fitting is that it is easily disassembled, that is, by using the correct size wrench, you simply unscrew the flare nut that makes up the flare-type connection, a simplified operation when it is necessary to make repairs.

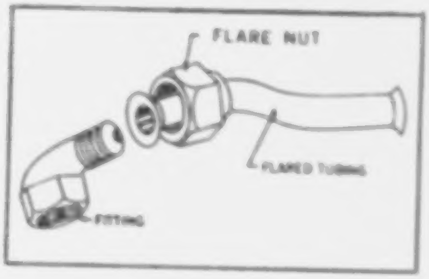


Figure 5-10. Flared Tubing and Fittings

Annealing

Hardened tubing has a tendency to split during the process of flaring and is not as easily worked as annealed tubing.

Before hardened tubing can be satisfactorily worked, it must be annealed. Annealing is the process of softening, in which the tube is heated to a dull cherry red and cooled naturally by air or in water. Copper is the only metal that can be softened by cooling in water.

When annealing copper tubing, it should be remembered that its melting point is approximately 1900° to 1980° F, and special care must be taken when heating with the oxyacetylene torch or other high temperature.

Rigidity or hardness can be induced in the copper tubing by stretching it, with blocks and tackle and come-alongs.

## Flaring with a Flare Block

To prepare the flare (see Figure 5-11), insert the end of the tubing into the correct size hole in the flaring block and extend the end of the tubing above the face of the block double the wall thickness of the tubing. (See Figure 5-11). This allows enough tubing to spread over the surface of the taper on the fitting. The clamp is then attached to the flaring block and the cone is centered over the end of the tubing. The cone is then screwed into the center of the tubing by rotating the handle on the clamp clockwise. (See Figure 5-11.) The tubing is then expanded just enough to fit into the flare nut and over the end of the fitting.

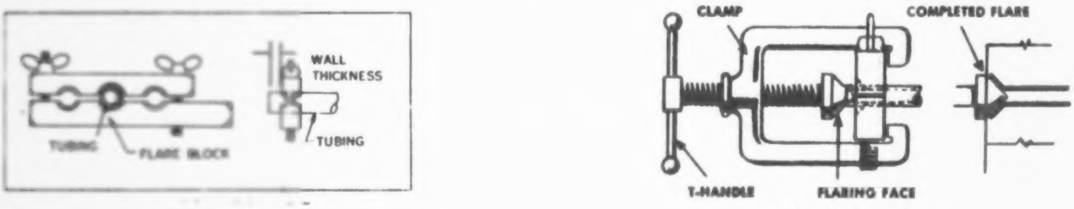


Figure 5-11. Flaring Tool

## Swaging Copper Tubing

Swaging is the process by which the end of the one piece of tubing is stretched or expanded in order that the end of another piece of tubing of the same size will fit into it, see Figure 5-12. The joint will then be sealed by soldering or brazing. By swaging the use of a fitting is eliminated.

Swaging can be used in close places where there is not room for fittings. A good swage connection will reduce the possibilities of leaks.

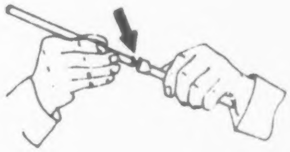


Figure 5-12. Swaging

Two types of swaging kits that we will discuss here are the standard and the universal swaging kits.

The standard swaging kit consists of a swaging punch and a swaging block, as illustrated in Figure 5-13. The swaging punch has a small portion (called a pilot) which fits easily into the inside of the tubing, and a tapered lead which connects this pilot with an enlarged portion which is slightly larger than the outside diameter of the tube.

Swaging with the standard kit should be accomplished as follows:

—— Use backside of block (side opposite bevel).

—— Clamp tube into proper size hole in block.

—— Extend tube above block a distance equal to the distance from the bottom of the swaging punch to the top of the bevel.

—— Hold block firmly in hand.

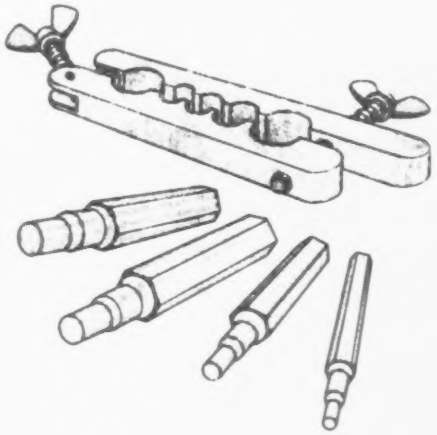


Figure 5-13. Standard Swaging Kit

- Using a hammer, drive the swaging punch into the tube (swaging punch should be turned slightly after each stroke.

The universal swaging kit consists of a conventional flaring block, swaging spreader and yoke. (See Figure 5-14). Swaging with universal kit should be accomplished as follows:

- Place tubing in conventional flaring block and extend above the face of the flaring block approximately 1/8" more than the diameter of the tube you are swaging. (Example: 3/8" tubing + 1/8" = 4/8" or 1/2")
- Tighten the flaring block down to prevent tubing from slipping. (Slippage will cause damage to tubing and swaging spreader.)
- Select the proper sized swaging spreader and screw into the yoke screw. (Example: 3/8" swaging spreader for 3/8" tubing)

  NOTE: The small spreader takes care of three (3) sizes: 3/16", 1/4" and 3/8" O.D. tubing. There is a separate spreader for every other size.
- Slip the yoke over the bar and turn in a clockwise direction so that it hooks the bar.
- Screw the spreader into the tubing (making sure to center it) until it gets to the point where the top of the upper shoulder on the spreader is bearing on the tube.
- Hold the yoke so it will not twist off the bar as you unscrew the spreader from the tube.

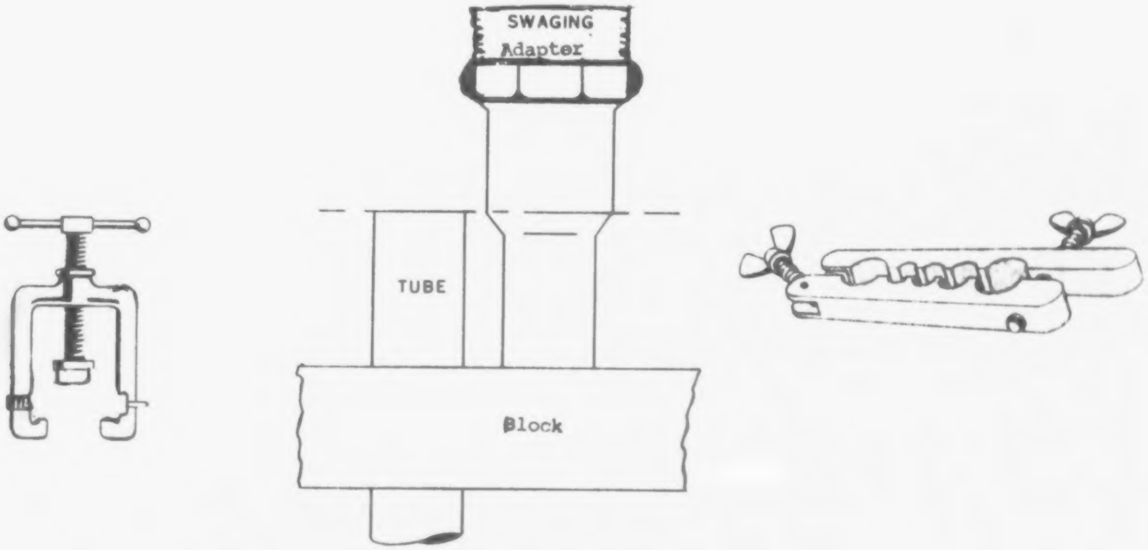


Figure 5-14. Universal Swaging Kit

The completed swage will have an inside diameter slightly larger than the original outside diameter of the tube and should always have a depth at least equal to the original outside diameter.

A swage should not be made within one inch of the point where a flare or a bend is to be located. The swaged portion of the tubing will have a double thickness, making it very difficult to bend. In flaring, it may be impossible to slip the flare nut back far enough on the tube to properly clamp the tube into the flaring block.

After the swage is completed, the next step is to clean the tubing with sand paper, steel wool or other material.

After cleaning, a thin uniform coating of noncorrosive soldering flux should be applied to the tube with a brush or paddle. Flux should not be applied with fingers or any oily subject. If the flux is applied too thickly, the excess flux may form bubbles when heated and prevent the solder from flowing into the joint. Do not dip tube into flux.

A noncorrosive flux is an antioxidizing agent and can only keep the metal clean once it has been cleaned mechanically. A corrosive flux must not be used in heating systems work, as it corrodes the metal.

A very important step in good soldering is that the materials being joined must be hot enough to melt the solder. This is the only way that solder will flow into the pores of the metal. After applying the heat, touch the solder to the metal to be soldered. If the metal is clean, fluxed and of the correct temperature, the solder will flow in to the pores of the metals to be joined by capillary attraction. If the solder is heated with the torch, a poor connection will result.

Connecting Flared Fittings

After you have flared the tubing, putting the joint together is very simple. Slip the flare nut up against the flare and then screw the nut into the flare fitting, as shown in Figure 5-15. Use two wrenches to tighten or loosen the joint. Make sure that your wrenches fit snugly, to avoid damaging the fittings. Do not use tools that will mar or scar the fittings. It is not necessary to exert excessive pressure when tightening the fittings because copper and brass are soft and contains a certain amount of lubricant that helps to seal them with a minimum amount of pressure applied. A properly flared copper connection will withstand up to 3000 psi (Figure 5-15).

A cross section view of a flared fitting is shown in Figure 5-16.

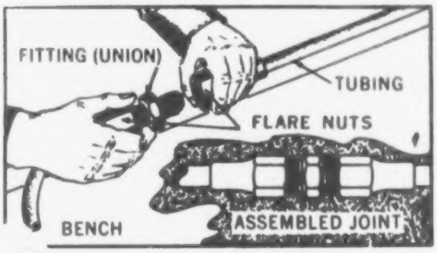


Figure 5-15. Parts and Assembled Joint

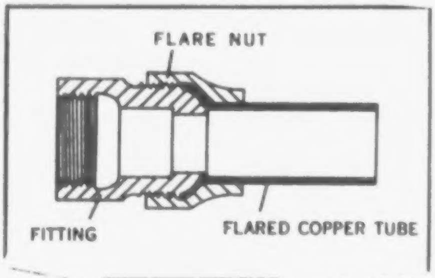


Figure 5-16. Cross Section of Flared Fitting

When you install a piping system, using copper tube, there are many different types of flare fittings to choose from. You may select any combination that fits the job. Figure 5-1 shows some copper fittings that are available to you.

Types of Solder

The heating specialist many times finds himself in a situation where two sections of copper tubing must be joined and there is not enough room to employ a flaring tool. This situation is where the soldering method of joint copper tubing should be used.

Soft Solder. One type of soft solder that is used on most soldering projects by the heating specialist is known as half and half. It is made with equal weights of tin and lead (50/50). This solder melts at approximately 360° F and is free flowing around 415° F. Soft solder is used on low pressure systems.

It takes considerable time and practice to become competent in soldering. Soldering is the process of applying a molten metal to hot metals that are not molten. The hot solder flows into the pores of the metals being joined and as it changes state from a liquid back to a solid, a strong joint is obtained.

To solder satisfactorily, the surfaces to be soldered must be very clean and must remain clean throughout the soldering process. Also, a sufficient quantity of heat must be used.

In soldering copper tubing, the outside surface of the tube and the inside surface of the fitting should be cleaned until the metal is bright. There should be no discoloration, grease, dirt or oxides remaining on the surface to be soldered. The cleaning method most generally used is to clean the inside and outside surfaces with steel wool or sandscreen.

## OPERATION OF THE HYDROCARBON TORCH

### Hydrocarbon Torch (Air-Acetylene Torch)

A high temperature concentrated flame that will quickly bring the fitting to the melting point of solder is the only heat that is necessary for "sweating" fittings on copper tubing. If it is at all possible, an air-acetylene torch, like the one illustrated in Figure 5-17, should be used. This type of torch consists of a small portable cylinder of acetylene gas, a regulator, hose and torch. The air-acetylene torch is very efficient and produces a good flame for soldering. The acetylene gas mixes with the atmospheric air to support combustion and produces a flame up to 4000° F.

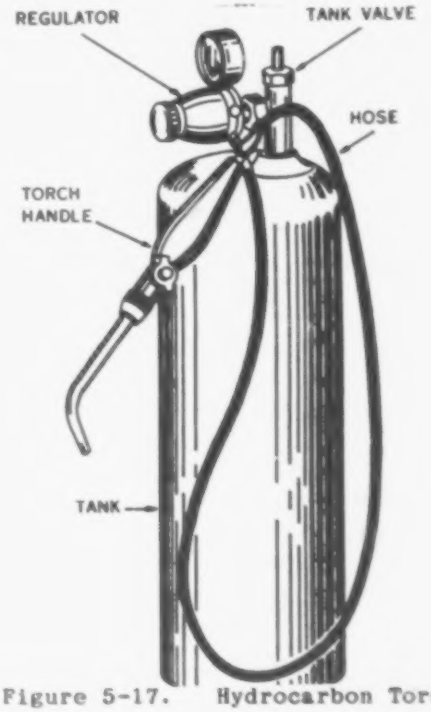


Figure 5-17. Hydrocarbon Torch

## PROCEDURES FOR SOLDERING

Sweat soldering is a method of joining two metals together by allowing molten solder to run between the tubing and fittings. The law of capillary attraction governs the force responsible for the bonding in solder joints. The tubing must be (1) cut to length, (2) reamed, (3) cleaned, and (4) bent, if necessary, before you are ready to solder the joint.

Your preparation of joints for soft soldering must be thorough. Metal surfaces must be perfectly clean at the joint to obtain a good bond between the base metal and the solder. You must remove all dirt, grease, oil, paint, etc., and must make the metal bright. Clean the tubing with a wire brush, file, emery cloth or steel wool. You may also use chemical cleaners. Make sure that the parts to be joined fit together very closely. The only additional thing that you need to make the joint is a thin film of free-flowing solder.

When the fitting and tubing are ready to be joined, apply heat evenly around the fitting. Do this by moving the flame back and forth. This procedure also keeps you from overheating the tube and fitting. Why is this important? Because if the connection is overheated, the flux may burn out, causing oxidation, and the solder will not spread evenly.

Also, of course, an overheated joint causes the solder to seep through the joint and flow away. You should therefore occasionally test the heat by touching the fitting with solder where the tubing and fitting join. Normally, thick wall fittings require more heat than thin wall fittings. When the tube and fitting melt the solder, the sweating may begin.

As soon as the connection is hot enough to melt the solder, remove the flame and apply the solder to the edge of the fitting where it comes into contact with the tube. Solder, when confined between two surfaces, will run uphill by capillary attraction. Joints can be made in any position.

The amount of solder required for a connection depends upon the diameter of the tube to be sweated. For instance, 1/4-inch of solder should be sufficient to solder a joint for 1/4-inch tubing, 1/2-inch of solder for 1/2-inch tubing, etc.

When a line of solder shows up around the fitting -- that is, a bead of solder appears in the groove at the end of the fitting -- the joint has all the solder it will take. When you apply solder to a tee, feed solder from both ends of the fitting. Reheat the fitting slightly to help the solder penetrate into the metal. Remove the flame and continue to feed the solder to make sure the joint is filled.

Allow the joint to cool for a short while. A rag or wad of waste, saturated with water, will hasten this cooling. When you cool male and female adapters, allow more time for the solder to set, because these fittings are heavier, they hold heat longer, and they do not cool as quickly.

When unsoldering a tube from a fitting on which other soldered conenctions are to be left intact, make sure that you will not melt the solder in the other connections. Keep the connections that are to be left intact cool by applying damp cloths to them. You may also use damp cloths to protect valves and other units from the intense heat. Make a shield from a sheet of asbestos paper and slip it over the tubing to protect combustible materials or a flammable wall while you are soldering.

## Oxyacetylene Combustion

The flame of a hydrocarbon torch will not heat the base metal hot enough for some soldering jobs. Therefore, when silver soldering, it is usually best to use an oxyacetylene flame. The oxyacetylene flame is derived from burning pure acetylene in the presence of oxygen. By using oxygen and acetylene, it is possible to obtain a flame hot enough to melt all commercial metals.

### Oxygen

Oxygen is a very common element and one we come in contact with daily. For example, water is about 88 percent oxygen, the air we breath is approximately 21 percent oxygen, and the earth is composed largely of oxides which are compounds of oxygen. Most of oxygen that is used commercial is obtained from the air. This is accomplished by freezing the air at -317° F. which separates the oxygen from the nitrogen and other gases.

Although oxygen will not burn, it supports combustion very actively, more so than air. This characteristic of oxygen makes it desirable to use with acetylene for soldering and welding.

### Acetylene

Acetylene is the fuel gas of the oxyacetylene flame. It is produced by dissolving calcium carbide in water. Calcium carbide is made by fusing limestone and coke in an electric furnace.

Acetylene is not an ordinary gas. It has characteristics peculiar in itself.

It contains about 93 percent carbon and about 7 percent hydrogen. When burned in the presence of pure oxygen, it burns at a temperature of 6000° F. Acetylene not only develops a large amount of heat, but also releases the heat units so rapidly that the highest temperature of the flame is produced almost instantly. At pressures greater than 15 psi, acetylene is unstable and may split up or disassociate. When pressure causes the gas to split up or decompose, this disturbance of the molecules release heat until an explosion of the gas is produced.

It requires two and one-half (2-1/2) parts of oxygen to consume completely one (1) part of acetylene. It is not necessary, however, to supply all this oxygen through the torch, because a portion of the oxygen is derived from the air surrounding the flame. The torch is designed to supply one (1) part of oxygen to every part of acetylene that passes through it.

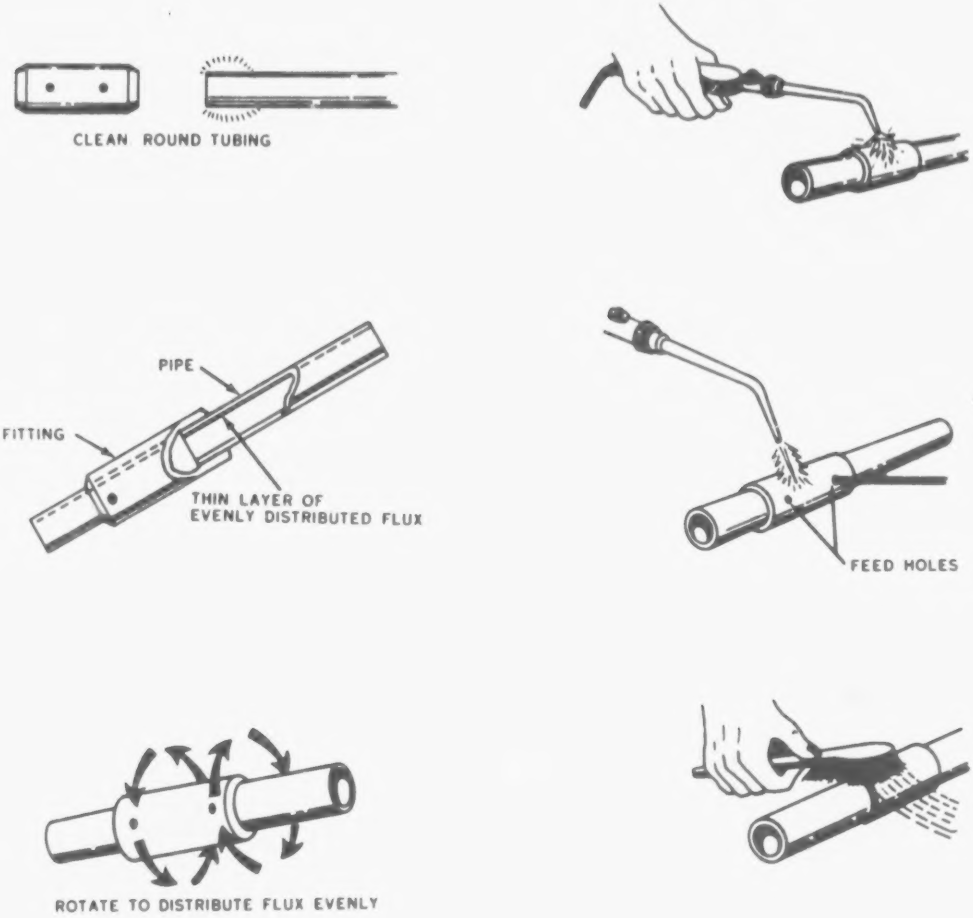

CLEAN ROUND TUBING
PIPE
FITTING
THIN LAYER OF
EVENLY DISTRIBUTED FLUX
FEED HOLES
ROTATE TO DISTRIBUTE FLUX EVENLY

Figure 5-18. Procedures for Soldering

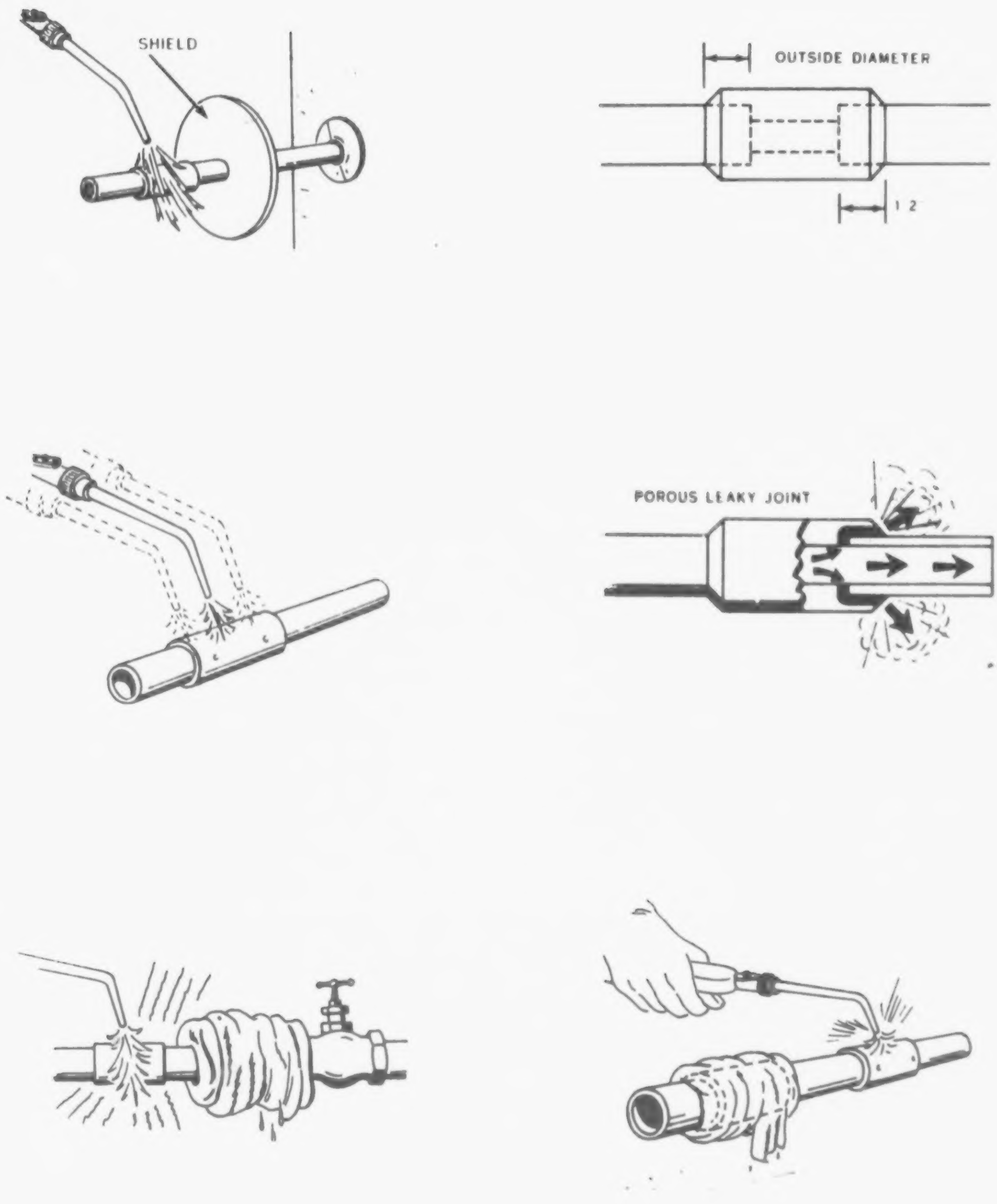

SHIELD
OUTSIDE DIAMETER
1 2
POROUS LEAKY JOINT

Figure 5-18. Procedures for Soldering (Continued)

Types of Flames

The oxyacetylene torch will produce three different types of flames. The heating specialist should be able to identify each of these flames and be able to adjust the regulators and torch to produce the type of flame required for each application.

_____ **NEUTRAL FLAME.** When the oxygen and acetylene are equally mixed, a neutral flame results (see Figure 5-19). A neutral flame is usually used for welding and cutting.

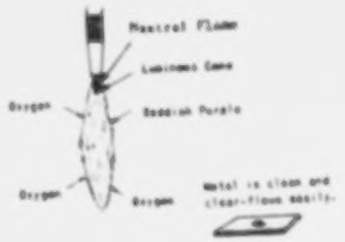

Neutral Flame
Luminous Cone
Oxygen
Reddish Purple
Oxygen
Oxygen
Metal is clean and clear-flows easily.

Figure 5-19. Neutral Flame

_____ **CARBURIZING FLAME.** The carburizing or excess acetylene flame (Figure 5-20) contains excess carbon. This flame is usually used for heating metal for soldering and brazing.

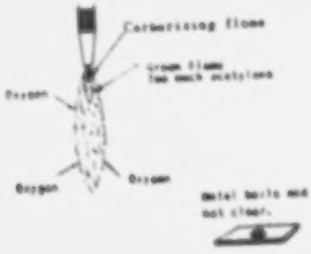

Carburizing flame
Green flame
Too much acetylene
Oxygen
Oxygen
Oxygen
Metal boils and is not clear.

Figure 5-20. Carburizing Flame

_____ **OXIDIZING FLAME.** The oxidizing flame (Figure 5-21) results from an excess of oxygen. We never use the oxidizing flame in heating. It is sometimes used by welders to melt rivets.

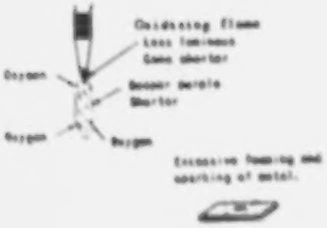
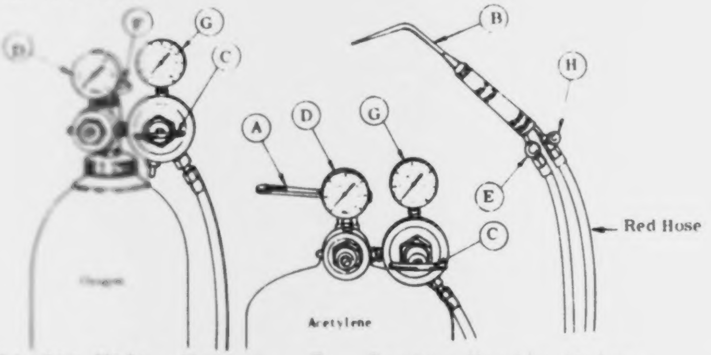

Oxidizing flame
Less luminous
Cone shorter
Oxygen
Deeper purple
Shorter
Oxygen
Oxygen
Excessive foaming and sparking of metal.

Figure 5-21. Oxidizing Flame

## OXYACETYLENE EQUIPMENT

The major items of the oxyacetylene equipment used in soldering are oxygen and acetylene cylinders, oxygen and acetylene regulators, gauges, hoses and torches (see Figure 5-22). Knowledge of all these items will aid you in becoming not only a good mechanic, but a safe one as well.



A - Acetylene Cylinder Valve Wrench
B - Torch Tip
C - Regulator Adjusting Screw
D - Cylinder Pressure Gauges
E - Oxygen Needle Valve
F - Oxygen Cylinder Hand Valve
G - Regulator Outlet Pressure Gauge
H - Acetylene Needle Valve

Figure 5-22. Identifying Acetylene Equipment

### Oxygen Cylinders

Oxygen is stored in cylinders of seamless steel made to withstand high pressure. The initial charging pressure of these cylinders at the plant is 2200 pounds per square inch at 70° F. Oxygen, like other gases, expands as it becomes heated. Oxygen cylinders have a bursting disc on the cylinder valve that will burst, should the pressure in the cylinder become too high.

### Acetylene Cylinders

There are several types of acetylene cylinders on the market. All are made in accordance with specifications set up by the Interstate Commerce Commision. The acetylene cylinder is filled with porous material such as limestone, coral rock, or cellulose, which absorbs acetone. Acetone, in turn, has the property of absorbing many times its own volume of acetylene gas, thus the acetylene is not a free state and is known as dissolved acetylene. Under such conditions, acetylene can safely be compressed to a pressure of 250 psi at 70° F. Acetylene cylinders have fusible plugs which melt when pressure and temperature become too high.

### Oxygen and Acetylene Regulators

The primary purpose of the regulators is to reduce the high pressure of the gases in the cylinders to the desired working pressure at the torch. Regulators also perform the function of maintaining a constant pressure in order that the flame may be perfectly steady and uniform.

Most regulators are either of the single-stage type or the two-stage type. Single-stage regulators reduce the pressure in one step or stage, while the two-stage regulators perform this same work in two steps or stages. Less adjustment is generally necessary when the cylinders are being used with two-stage regulators.

Regulators should always be turned off before turning on high-pressure gases to protect the regulator valve seats.

Gauges are parts of the regulator assembly. There is one high-pressure and one low-pressure gauge for each assembly (See Figure 5-22). The high-pressure gauge shows the pressure of the oxygen or acetylene in the cylinder. The low-pressure gauge indicates the working pressure at the torch.

### Hoses

The hoses that connect the regulator to the torch are built to withstand internal pressure. The red hose has left-hand threads and is connected to the acetylene regulator. The green hose or black hose has right-hand threads and is connected to the oxygen regulator.

### Torches

The torch is the unit used to mix the oxygen and acetylene in the correct proportions and to help control the volume of these gases burned at the tip. The torch handles are designed with two needle valves, one for adjusting the flow of acetylene and the other for adjusting the flow of oxygen.

There are two general types of torches, the low pressure or injector type and the medium or balanced pressure type. In the low pressure type, the acetylene may be used at less than 1 psi.

There are two general types of torches, the low pressure or injector type and the medium or balanced pressure type. In the low pressure type, the acetylene may be used at less than 1 psi.

In an injector type torch, a jet of high pressure oxygen is necessary to produce a suction effect which draws in the required amount of acetylene. This is illustrated in Figure 5-23. In the medium pressure torch illustrated in Figure 5-24, the acetylene is operated at from 1 to 15 psi. These torches are designed to operate at equal pressures of acetylene and oxygen. You will use this type of torch in this course.

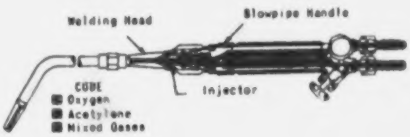


Figure 5-23. Low-Pressure or Injector-Type Torch

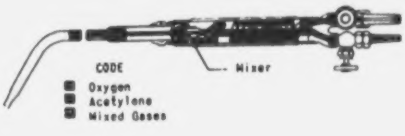


Figure 5-24. Medium or Balanced Type Torch

### Torch Tips

Various brazing and soldering jobs require differences in the total amount and concentration of heat. To obtain this difference, most torches have several tips of various sizes that can be exchanged conveniently and quickly.

The torch tip sizes are designed by numbers and each manufacturer has his own arrangement for classifying them. The manufacturer's charts should be used when selecting tips for different thicknesses of metal to be soldered or brazed.

Proper tip sizes and working pressures for the balanced-pressure type torch are:

| TIP SIZE | ACETYLENE PRESSURE | OXYGEN PRESSURE |
|---|---|---|
| 00 | 1 psi | 1 psi |
| 0 | 1 psi | 1 psi |
| 1 | 1 psi | 1 psi |
| 2 | 2 psi | 2 psi |
| 3 | 3 psi | 3 psi |
| 4 | 4 psi | 4 psi |
| 5 | 5 psi | 5 psi |
| 6 | 6 psi | 6 psi |

Torch tips are made of copper alloy and are made so that they seat well when tightened hand-tight. Torch tips should not be rubbed across abrasive firebrick or used as tongs to position work. When torch tips become clogged, they must be cleaned with torch tip cleaners. Care should be exercised in cleaning tips so that the orifices are not enlarged. A partially clogged tip can cause popping of the torch.

CAUTION: Failure to tighten the tip in the handle or a scratched seat can result in a fire. (Burning of acetylene where tip screws into handle). A flashback can occur when there is not enough pressure to keep the flame outside of the tip. Burning of acetylene inside the tip produces a high pitch noise.

Inspection and Maintenance

Oxyacetylene equipment has been designed to operate without lubricants. Visual inspections for wear, leaks and malfunctions should be made each time the equipment is used. It is most important that equipment be kept clean at all times. The presence of grease or oil with oxygen under pressure will cause spontaneous combustion. If troubles do appear in oxyacetylene equipment, consult TO 34W4-1-5 for corrective measure to be taken.

## SAFETY PRECAUTIONS WHEN USING OXYACETYLENE EQUIPMENT

An important thing for one to remember when performing an activity is to work SAFELY. The oxyacetylene equipment is not hazardous, but it must be remembered that the mechanic is working with gases of high pressure and the hotest flame known to man. In view of this, certain precautions are necessary for safety. The following are precautions that a mechanic should know so well that they become automatic in his actions.

1. NEVER use oil on oxyacetylene equipment. Oxygen under pressure is likely to cause an explosion if it comes in contact with oil or grease. If the threads of a connection will not work smoothly, merely rub the lead of a pencil on the threads. Sufficient graphite will be deposited to provide lubrication.

2. Wear suitable clothing. Clothing should be free of oil and grease. If clothing is of the type that will burn readily, use a leather apron.

3. Call oxygen by its proper name. Do not refer to oxygen as air, for if used in place of compressed air on oil or grease, you may cause an explosion.

4. Do not refer to acetylene as gas. Refer to it as acetylene.

5. Do not release oxygen or acetylene in confined spaces. This sets up not only a fire hazard but an explosive hazard.

6. Wear proper goggles. Adequate eye protection should be afforded at all times.

7. Do not use acetylene at pressures greater than 15 psi. Acetylene gas, dissolved in acetone and contained in an acetylene cylinder, tends to disintegrate and an explosion may result.

8. Use a friction lighter to light the torch. Although the torch an be lit with a match, serious burns can result.

9. Do not use cylinders for supports or forming dies.
10. NEVER lay the torch down and walk off leaving it burning.
11. Do not burn the place down. Torches in careless hands can be dangerous. Do not burn your hose or your buddy. Be careful and use common sense with a lighted torch.
12. Do not work on containers that have been used to hold gas or combustible materials. If it is necessary to braze a container that has contained combustible materials, steam-clean it thoroughly and drift dry nitrogen through it during the brazing process.
13. Do not store oxygen with acetylene, propane, gasoline or other fuels.
14. NEVER transfer acetylene from one cylinder to another.
15. If you should start a fire, shut off your acetylene cylinder before doing anything else.
16. Should a flashback occur, shut off the acetylene, relight and, if necessary, increase the oxygen to the tip.
17. When not in use all caps must be on the tank.
18. All cylinders will be stored in upright position and chained.

## PROCEDURES FOR SILVER SOLDERING

Silver soldering is the process of joining metals together by the use of a silver alloy with a melting temperature between 1000° to 1150° F. These alloys contain around 45 percent silver.

One of the essentials of a silver soldered joint is that there be contact between absolutely clean surfaces. The first act of cleaning may be done with a scraper, file, emery cloth or steel wool. A metal that has been cleaned immediatly oxidizes on exposure to air. The layer of oxide, no matter how thin, will not form an alloy with another metal; therefore, soldering cannot be performed between oxidized surfaces. However, a certain amount of oxidation cannot be avoided; for this reason, fluxes are used to help prevent oxides from forming. A good flux is necessary when silver soldering. The flux is needed to prevent oxides from forming on hot metals.

Phos-copper is another type of silver alloy and may be used to join copper to copper without using flux. This type of alloy has the flux or cleaning agent built into the rod. It is an advantage to use no flux when the tubing or parts are joined in a system which should be kept clean.

## PROCEDURES FOR WELDING

Prepare Metal

SPECIFICATIONS

_____ Reinforcement. Should be 1/16" minimum.

_____ Bead Width. Should encompass the beveled area not to exceed 1/16" on either side of the bevel.

_____ Appearance. The completed specimen must be of uniform quality; the surface area will not be overheated or appear to be oxidized.

NOTE: Oxidized areas will not be accepted.

_____ Penetration. 75 to 100 percent.

NOTE: Your metal should look similar to Figure 5-25.

NOTE: Base metals one-eighth inch thick or less do not require beveling.

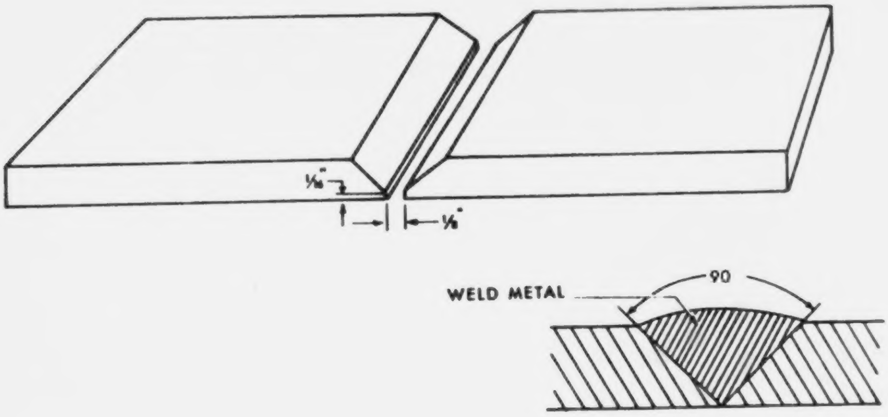


Figure 5-25. Metal Blocks for Welding

A small puddle should be formed on the surface when making a bead weld with a welding rod. The welding rod is inserted into the puddle and then the base plate and rod are melted together. The torch should be moved slightly from side to side to obtain good fusion. By varying the speed of welding and the amount of metal deposited from the welding rod, the side of the bead weld can be controlled to any desired limit (See Figure 5-26).

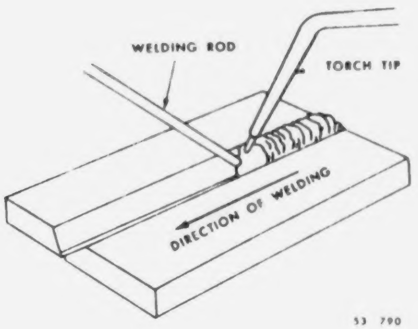


Figure 5-26. Forehand Welding

You will puddle a two-inch weld bead. After successfully completing the puddling, you will weld a bead using a filler rod.

SPECIFICATIONS

_____ No burn-through of holes.

_____ Penetration 75 percent.

_____ Even in width of 2 to 4 thicknesses.

_____ Even in height.

_____ Weld must be free of iron oxide.

1. Assemble oxyacetylene welding equipment:

    _____ Select tip size.

    _____ Oxygen pressure 15 psi.

    _____ Acetylene pressure 5 psi.

2. Select material:

    _____ Low carbon steel plates.

    _____ Filler rods.

3. Select welding equipment:

    _____ Pliers.

    _____ Brush.

    _____ Igniter.

    _____ Goggles.

4. Light torch:

    _____ Use igniter.

    _____ Adjust to neutral flame.

5. Position metal sheet on the welding table so that it will be easy to move the torch from right to left.

6. Hold the torch in a comfortable, balanced position in the hand. Point the flame in the direction of the weld at about 45 degrees.

7. Begin the weld at the right-hand edge of the metal. Lower the torch until the inner cone is about 1/8-inch from the metal surface.

8. Keep the flame moving in a small circle until a pool of molten metal begins to form. When the puddle becomes about 1/4-inch in diameter, begin by moving it across the sheet by slowly moving the torch in overlapping circles.

9. Slowly work the puddle along the surface so that the metal in front of the puddle preheats evenly. This will produce a weld with even arc-shaped ripple.

10. Stop the weld about 1/2-inch from the edge of the sheet.

11. Practice making puddle welds. Keep the weld the same diameter and as straight as possible.

12. Use the procedure outlined above for puddling; add a filler rod to the molten pool.

    _____ Rod held inside flame envelope.

    _____ Filler rod at about 45 degrees.

    _____ Allow rod to melt in the molten pool adding it to the leading edge of the molten pool.

    _____ Height can be maintained by the amount of filler material.

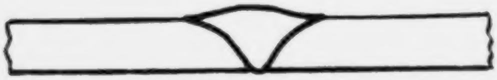
13. Restore the welding equipment to its original position.

## CHARACTERISTICS OF GOOD AND BAD WELDING JOINTS

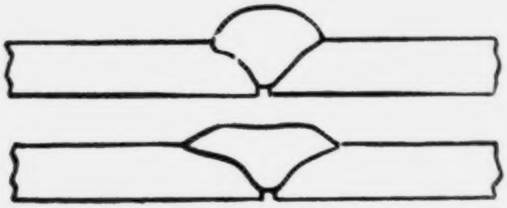
Compare your weld to the illustrations and determine what improvement could be made.

CHARACTERISTICS OF GOOD AND BAD WELDING JOINTS

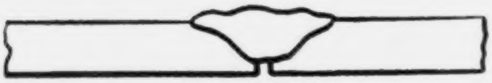
Compare your weld to the illustrations and determine what improvement could be made.



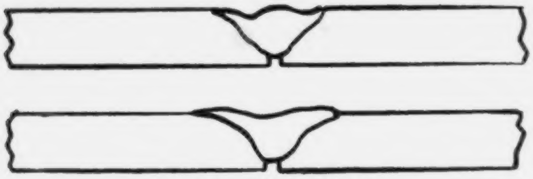
CORRECT WELD CONTOUR



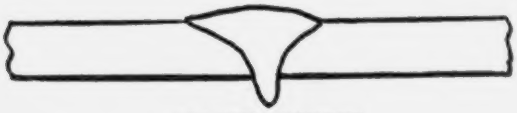
EXCESSIVE REINFORCEMENT



LACK OF PENETRATION



UNDERCUTTING OR "VALLEYS"



WELD METAL PROTRUDING

Figure 5-27

## SUMMARY

The ease of handling and high heat conductivity makes copper tubing highly desirable for use in refrigeration systems. Copper tubing is divided into five different types; however, the heating specialist usually uses only the types that are for heating service.

There are two main types of fittings used in heating work. These are the flare and sweat types. The flare type is used where there may be a reason for opening the line at some future date. The sweat type fitting is usually cheaper and easier to install so they should be used whenever possible.

In the heating career field you, as a mechanic, will have many opportunities to repair leaks and fabricate tube, which will require the use of soldering and good welding methods. Now that you know the proper methods for soldering and welding, you can apply these methods at your next duty station and can assure a trouble-free system.

## QUESTIONS

1. When is a flared connection considered to be an airtight and watertight connection?

2. Which method of bending tubing is most practical?

3. What is the melting point of copper tubing?

4. How far above the face of the flaring block should the tubing extend when making the flare?

5. Name two types of solder.

6. How many parts of oxygen are required to consume one part of acetylene?

7. What are the three types of oxyacetylene flames and how can they be recognized?

8. What temperature is attainable with acetylene flame?

9. Oxygen is stored in cylinders at what pressure?

10. Acetylene is stored in cylinders at what pressure?

11. How far should the tubing extend out of flaring block to get a good swage?

## REFERENCES

TO 34W-4-1-5, Welding -- Theory and Application.

J3ABR54532 001-V-1 thru V-5

Technical Training

# Heating Systems Specialist

# HOT WATER HEATING SYSTEMS

May 1983

3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
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This workbook contains practical work assignments for you to accomplish in conjunction with your study assignments. Complete each problem or work assignment in the sequence given and it will aid you in understanding and retaining the key points covered in each assignment.

## TABLE OF CONTENTS

## WORKBOOKS J3ABR54532 001-V-1 thru V-5

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| V-5 | Soldering and Welding | 5-1 |

# HOT WATER HEATING AND CONTROLS

## OBJECTIVES

Using information given, explain the principles of operation of low/medium temperature hot water boilers by correctly answering 20 out of 25 questions.

Using information given, explain the proper procedures to remove a boiler from service, drain, flush and fill boiler, install, operate and maintain centrifugal pumps, charge expansion tank, perform preoperational inspection and fire boiler by correctly answering 12 out of 15 questions.

## EXERCISE 1

## HOT WATER HEATING AND CONTROLS

Complete the following statements.

1. How is low temperature water usually applied when used for space heating?

2. What is meant by a hot water system that heats directly?

3. What type of hot water heating system is suitable for any size installation?

4. How does a centrifugal pump pump water?

5. Why must a centrifugal pump never be run dry?

6. How often should a centrifugal pump be operated?

7. What should be accomplished on a semiannual inspection of a centrifugal pump?

8. When should wear rings be replaced?

9. How are low temperature hot water boilers classified?

10. What are the types of steel boilers?

11. How many sections are steel boilers constructed in?

12. What is the purpose of the pressure relief valve?

13. What is the purpose of the dip tube on a hot water boiler?

14. What device is added to a hot water boiler to prevent thermal shock?

15. Why should an inlet connection be the same size as the boiler inlet?

16. A ________________________________ prevents gravitational flow of water through the system when the circulating pump is shut off.

17. What is the purpose of the breeching?

18. Why are expansion tanks added to a hot water system?

19. What is the maximum temperature that can be used on an open tank hot water system?

20. Where should an open expansion tank be installed?

21. What is the advantage of using a closed expansion tank over an open tank?

22. What components are added to an open expansion tank?

23. How large must an expansion tank be?

24. How is a closed hot water system automatically supplied with water?

25. At what pressure are pressure regulating valves factory set?

## EXERCISE 2

Complete the following statements:

1. What should be the first step in shutting down a hot water boiler?

2. How long should water circulation be maintained through the boiler when shutting the unit down?

3. When flushing a hot water boiler, how long should fresh water be run through the boiler?

4. What would be the first procedure to follow when filling a hot water system?

5. How much water should be added to the expansion tank when filling the system?

6. When should you begin venting air from a hot water system?

7. Why is it necessary to drain and refill the system several times before starting the fire for initial operation?

8. When performing a preoperational inspection, the piping system should be checked for ______________________________________________________________

______________________________________________________________________

______________________________________________________________________.

9. Why should a newly filled system be heated to a higher temperature than anticipated for normal operations?

10. What procedure should be accomplished on a newly installed system after two days of operation?

11. How often should a hot water system that has been flushed and vented be drained?

12. What will a stoppage in the system cause?

13. What will happen if a relief valve fails to operate?

14. What can happen if the water temperature gets too high?

15. If the system pressure fluctuates or pulsates rapidly, what should you check?

# HOT WATER DISTRIBUTION SYSTEMS

## OBJECTIVES

Using information given, explain the types of hot water distribution systems and their components by correctly answering 10 out of 15 questions.

Using information given, explain the procedures to follow to install a secondary hot water heating system by correctly answering 2 out of 3 questions.

## PROCEDURE

## EXERCISE 1

## HOT WATER DISTRIBUTION SYSTEMS

Complete the following statements.

1. What type of hot water system would you use that did not require room-to-room heating adjustment?

2. How does the one-pipe system differ from the series loop system?

3. The advantage of a one-pipe system over a series loop system is ____________________
____________________________________________________________________.

4. How are two-pipe systems classified?

5. What is the biggest problem with the direct return heating system?

6. What type of hot water system is easiest to balance?

7. Why are expansion joints added to a hot water distribution system?

8. How is air removed from a hot water system?

9. Where must air vents be installed?

10. What are the methods of balancing a hot water system?

11. When is the ideal time to balance a hot water system?

12. In a single-zone system, what does the thermostat control in most cases?

13. When the water reaches the desired temperature, what does the aquastat do?

14. What can the thermostat control in a multiple-zone installation?

15. What methods are used to transfer the generated heat?

16. What is the heating medium used on secondary heating systems?

17. How is temperature control of a secondary system accomplished?

18. See figure 2-11, what causes the valve to close off?

# TROUBLESHOOTING HOT WATER HEATING SYSTEMS

## OBJECTIVES

Using information given, explain the procedures to follow in troubleshooting a hot water heating system by correctly answering 12 out of 15 questions.

Using information given, explain how to inspect and replace aquastats, maintenance of pressure regulators, procedures to follow to inspect and maintain special flow fittings, installation of air-bleed and pressure regulators, procedures used to balance system and inspecting boilers for leaks, corrosion, and scale by correctly answering 12 out of 15 questions.

## PROCEDURE

### EXERCISE 1

### TROUBLESHOOTING OF HOT WATER HEATING SYSTEMS

Complete the following statements.

1. What part of the boiler is considered the fireside?

2. If firing with coal you noticed that there was too little coal on the fuel bed, what should you do?

3. Before you begin to troubleshoot an oil burner, you first have to ______________________________________________.

4. Which type of fuel supply system is easiest to troubleshoot?

5. When troubleshooting a gas burner, you can atribute the problem much of the time to ______________________________________________.

6. Where do leaks occur on a hot water heating system?

7. How can you tell in a closed system that there is a leak?

8. What types of problems are encountered with circulating pumps?

9. How can you tell if an impeller is beginning to wear out on a circulating pump?

10. What should you check when replacing an old pump motor?

11. A high water level in the expansion tank would indicate a loss of the air cushion. True or false?

12. How is the air cushion in the expansion tank replaced?

13. If after replacing the air cushion in th expansion tank you again loose the cushion, what should you do?

14. How could a pressure regulator cause you to loose system pressure?

15. If you diagnose the problem as being a defective regulator, what should you do?

## EXERCISE 2

Complete the following statements.

1. What is the only adjustment made on an aquastat?

2. The differential setting on an aquastat determines ____________________________________

____________________________________________________________________________.

3. If an aquastat fails to properly maintain boiler water temperature, what should you do?

4. Before attempting to service or repair a pressure regulator you should ____________

____________________________________________________________________________.

5. What is the purpose of tapping the side of a regulator valve with a wrench?

6. How can you tell if the diaphragm of a pressure regulator has ruptured?

7. Where should a pressure regulator be installed?

8. What should be done before installing a pressure regulator?

9. What can happen if a pressure regulator is improperly adjusted?

10. How much pressure is necessary for a system that is 37 feet high?

11. What should you do if you see that an automatic air vent is leaking?

12. How do you inspect special flow fittings?

13. After opening up the piping system you notice that there is scale buildup on the special flow-fitting, what should you do?

14. How can you tell if a hot water system needs to be balanced?

15. When is the best time to balance a hot water system?

16. In order to balance a hot water system correctly the outside temperature should be low enough to require ______________________________________________________________

______________________________________________________________.

17. True or False. When balancing a hot water system all valves must be open.

18. After a hot water system has been adjusted, what should you do?

19. How often should a hot water boiler be opened up and inspected?

20. Where do leaks usually occur on a hot water system?

# OPERATION AND MAINTENANCE OF HOT WATER SYSTEMS

## OBJECTIVES

Using information given, remove a boiler from service, drain, flush and fill boiler with instructor assistance.

Using information given, inspect boiler for leaks, inspect and replace aquastats, and maintain pressure regulators with instructor assistance.

Using information given, inspect for corrosion and scale and troubleshoot hot water heating system with instructor assistance.

## PROCEDURE

### EXERCISE 1

### OPERATION AND MAINTENANCE OF HOT WATER HEATING SYSTEM

Safety

a. Remove watches, rings and jewelry; i.e., ID tags, armbands, etc.

b. Disconnect electrical power from power source.

c. Observe safety precautions that apply when working with operating heating equipment.

Drain Boiler

a. Make sure water supply to pressure regulator is shut off.

b. Open all valves to systems.

c. Lift cover plate in front of boiler out of the way to expose pit.

NOTE: Ask instructor for forks to lift plate.

d. Open drain valve on expansion tank.

e. Open drain valve on front of boiler.

NOTE: Wait for boiler to drain. When told to do so by instructor continue on to next step.

Flushing Boiler

In order to flush boiler proceed as follows:

a. Open raw water bypass.

b. Open raw water supply valve.

c. Close off supply valve when water pressure from boiler drain builds up.

d. Wait for fresh water to drain from boiler. Note color of water coming out. If it is still rusty looking fill and flush again. Do this until water runs clean.

Inform instructor when you are ready to continue.

Maintaining Boiler

a. Obtain tools from tool locker.

b. Place floor plate over pit.

c. Disconnect wiring from aquastat.

d. Remove bolts from plate holding aquastat.

NOTE: Hold onto aquastat so it doesn't fall.

e. Pull plate and aquastat from boiler and take to workbench.

f. Examine aquastat and plate for defects.

Inform instructor of your findings.

g. Obtain flashlight from tool locker and visually inspect boiler for scale, corrosion or any other defects.

Discuss findings with instructor.

h. Remove gage glass from expansion tank. Check glass for cracks or any other defects.

Discuss findings with instructor.

i. If okay, reinstall gage glass.

NOTE: Do not over tighten nuts.

j. Check condition of all valves, i.e., flow control valves, gate valves, pressure relief and pressure regulating valves.

Inform instructor of your findings.

k. If everything is okay and told to do so by instructor, put boiler back together.

Inform instructor of your findings.

l. When told to do so by instructor, reinstall pump.

Filling the System

a. Close drain on boiler and expansion tank.

b. Close vent on airtrol tank fitting.

c. Close all vents.

d. Open boiler supply and return main valves.

e. Open manual feed valve and feedwater. Fill system until expansion tank is approximately one-half full.

f. If level in tank is above or below one-half full, add or drain water and air as per instructions from instructor.

g. Set pressure regulator to maintain 12 psig.

STOP: Wait for any further instructions from instructor before proceeding.

h. Turn on power.

i. Start the circulating pump to establish water circulation. Check operation of pump for noise, vibrations, etc.

j. Begin venting system with lowest radiation.

k. Vent the rest of the units progressively until all radiators are completed.

l. If necessary, drain and refil system several times to remove any grease, core sand and other foreign material.

### Preoperational Inspection

Before starting the system, perform a preoperational inspection. Inspect the installation carefuly and make sure the following are completed.

### Boiler Unit

a. All installation, repair and cleanup work completed.

b. All piping tested for leaks, and insulation if necessary.

c. Drain valves closed, supply and return header valves open and in good condition.

d. Water gage glass on expansion tank properly installed, with valves open.

e. All auxiliary equipment (such as fuel burning, feedwater, limit controls) properly installed and ready to operate.

f. All instruments and gages properly installed and ready for operation, pressure relief valve set and in good condition.

g. All access and observation doors closed.

### Space Heating Equipment

All installation, repair and cleanup work on radiators, convectors, unit heaters, completed and ready for operation.

STOP: Do not continue until told to do so by instructor.

### Operational Procedures

a. Open fuel supply lines. (Solenoid switch, supply and return valves on oil tank, supply and return lines on fuel oil pump.)

b. Set aquastat to hot setting.

c. Turn on main power switch (side of boiler).

d. Burner should ignite. If burner does not fire correctly, consult instructor.

e. When water temperature reaches 120°F, turn thermostat to highest position.

f. Check water level in gauge glass on expansion tank. Maintain 1/2 full.

g. Trace out distribution system. Determine whether it is a one- or two-pipe, direct- or reverse-return system.

h. Bleed air from system as per instructions from instructor.

### Checks to be Made While Operating the Hot Water System

a. Check boiler and piping system for water leaks.

b. Check all valves on supply and return mains for proper operation.

c. Check all air vents for proper operation.

d. Check all boiler controls for proper opration.

e. Check for frayed wiring or loose connections.

f. Check expansion tanks for leaks and proper operation.

g. Check makeup waterline for leaks.

Shutdown Procedures

a. Turn aquastat to lowest position.

b. Turn off fuel supply. Close supply and return lines to fuel oil pump.

c. Set thermostat to lowest point when instructed by instructor.

d. Secure power (main power swtich on side of boiler).

# SOLDERING AND WELDING

## OBJECTIVES

Given information, explain basic facts about types and sizes of copper tubing and fittings by correctly answering 80% of questions.

Given hand tools, copper tubing kit, copper tubing, and instructions, measure, cut, bend, swage, and flare the copper tubing with a maximum of two instructor assists.

Given hand tools, sandpaper, steel wool, hydrocarbon torch and assortment of fittings, use proper techniques to soft solder two copper tubing joints with a maximum of two instructor assists.

Given information, explain the theory of oxyacetylene welding and related equipment by answering 80% of the questions.

Given hand tools, copper tubing, oxyacetylene equipment, sil-phos, and flux, use proper techniques to hard solder two copper tubing joints with a maximum of two instructor assists.

Given hand tools, metal, oxyactylene equipment, and sandpaper, use proper techniques to weld two pieces of metal together with at least 80% penetration with a maximum of two instructor assists.

## PROCEDURE

### EXERCISE 1

### TYPES AND SIZES OF COPPER TUBING

Answer the following questions.

1. What sizes are available with type M copper tubing? ______________________________
2. Name four types of copper tubing?

    a.

    b.

    c.

    d.

3. How is the diameter of copper tubing measures? ______________________________
4. Which type of copper tubing is used for high pressure and underground installation?

    ____________________________________________________________

5. Which type of copper tubing is used in non-pressure applications?

    ____________________________________________________________

### EXERCISE 2

### COPPER TUBING SYSTEM

CAUTION: Observe safety precautions when using hand tools. Exercise care while using tubing cutter and insure that reamer is folded in, to prevent puncture wound. Remove watches and rings prior to entering work area.

1. Proceed to lab area with instructor.
2. Draw flaring kits and copper tubing from supply cabinet.
3. Inspect tools and insure good condition.

MEASURING

1. Select a roll of tubing and unroll approximately two feet.
2. From your instructor, obtain measurement desired; then, measure tubing and mark it.
3. Write desired measurement in the blank space.

CUTTING COPPER TUBING

1. If a tube cutter is not available, what may be used to cut the tubing?

   ------------------------------------------------------------

2. Install the tubing cutter so that the cutter wheel is over the mark. Make sure that the reamer is folded in.
3. Tighten the cutter wheel slightly against the tubing and revolve the cutter slowly around the tubing one complete revolution to mark tubing.
4. Measure tubing again to insure correct length.
5. Continue revolving cutter, tightening slightly (1/4) after each complete turn, until the tube is cut through.

   CAUTION: Be careful not to drop the cutter and tube when the cut is complete.

6. Remove the cutter and insert reamer in the end of the tubing. Revolve the reamer until the burr is removed from the inside of the tubing.
7. Inspect the tube. If it is still rough on the end, smooth it by filing it very lightly.

   NOTE: The reaming procedures should be done with the open end of the tube pointing down, so the filings will not fall into the tube.

BENDING COPPER TUBING

1. Check with instructor to see what bends are to be made in the tubing.
2. Using the mechanical bender, make a 90° bend.
3. What other methods of bending copper tubing can be employed?

   a. ------------------------------------------------------------

   b ------------------------------------------------------------

   c. ------------------------------------------------------------

PROCEDURES FOR FLARING COPPER TUBING

1. Place the correct size flare nut on the tube.

   NOTE: Example 3/8" tubing - 3/8" flare nut.

2. Insert the tubing into the correct size hole in the flare block (beveled end). How far should tubing extend above the flare block? ______________________________

3. Tighten the wing nuts on the flare block as tight as possible with your fingers.

   NOTE: Use the T-handle to tighten the wing nuts on the flaring block.

4. Insert the flaring yoke over the tubing in the flare block.

5. Tighten T-handle, moving the flaring face into the center of the end of the tubing. Continue tightening until the flare is complete.

   NOTE: Tubing is flattened out over the face of the flaring block.

6. Remove the flaring yoke.

7. Loosen wing nuts with T-handle and remove tubing from flare block.

8. Slide flare nut to flared end and inspect adequate coverage of flare-nut bevel.

CONNECTING FLARED FITTINGS

1. Place flared end of tubing against rounded joint of fitting.

2. Slip flare nut up to flare.

3. Connect fitting and screw it on by hand until snug.

4. Tighten with line wrench and an open wrench.

   NOTE: Pipe joint or anti-seize compound is not required with flared connections.

PROCEDURES FOR SWAGING COPPER TUBING

1. State purpose of swaging copper tubing. ________________________________________

   ______________________________________________________________________________

2. Lay out and inspect tools.

   a. Swaging kit

   b. Hammer

   c. Tubing cutter

   d. Hacksaw

3. Cut and ream three pieces of copper tubing four inches in length.

   NOTE: Ream tubing until swaging tool fits into the pieces of copper tubing.

4. Insert one piece of the copper tubing in the swaging block.

   a. Use flat side of swaging block.

   b. Extent tube above block the distance from the bottom of the swaging tool to the top of the first bevel.

5. Extend the proper size swaging tool in the tubing.

   Example: 3/8" tubing - 3/8" swaging tool

6. Use light strokes with a ball peen hammer and drive the swaging tool into the tubing.

NOTE: The swaging tool should be turned slightly after each stroke.

NOTE: The swaging tool should be driven into the tubing until tubing reaches top of swaging tool.

7. Remove the swaging tool.

8. Remove the tubing from the swaging block.

## EXERCISE 3

## PROCEDURES FOR SOFT SOLDERING

1. Thoroughly clean all metal joining surfaces.

NOTE: Metal surfaces must be very clean before they will solder correctly. What can be used to clean the metal surfaces?

_______________________________________________

2. Apply a noncorrosive flux to cleaned area.

NOTE 1: Use a brush or paddle to apply flux - DON'T USE FINGERS or any oily object.

NOTE 2: Do not apply the flux too thickly as excess flux may form bubbles when heated and prevent the solder from flowing into the joints.

NOTE 3: Do not dip tube into the flux (same as Note 2).

3. After the tube has been inserted into the fitting, revolve it once or twice to spread the flux evenly.

4. Place tubing in brace on table.

5. Light the torch.

NOTE: Follow step-by-step procedures in lighting and adjusting torch.

6. Apply the flame to the fitting so solder will be drawn in by capillary attraction.

7. Test the heat of the metal by occassionally touching it with the solder.

CAUTION: Do not let the flame touch the solder.

NOTE: Oxidation will occur.

8. Hold the flame on the tubing and apply the solder to the edge of the fitting. Explain what will happen if the fitting is hot enough.

_______________________________________________

_______________________________________________

NOTE: The metal must be hot enough to melt the solder on contact.

NOTE: If you have 3/8" tubing you should use 3/8" solder.

9. Secure the torch.

NOTE: Follow step-by-step procedures.

10. Use a wire brush to remove excess solder from outside of tubing.

CAUTION: Lift hot tubing with pliers and cool in water bucket at the end of the workbench.

11. Have the instructor check your work.

12. The instructor may have you cut your completed joint to check the condition of your soldered surface.

## EXERCISE 4

## SETTING UP EQUIPMENT

### Cylinders

Place the oxygen and fuel gas cylinders together where they are to be used, and secure them from falling (see figure 1). Cylinders must be chained or otherwise secured ty cylinder cart, wall, workbench, post, etc.

NOTE: Both oxygen and fuel cylinders (especially oxygen) are highly pressurized and must always be handled with care. Never allow cylinders to be dropped, knocked over or subjected to excessive heat. When moving cylinders, always be certain valve protection caps are securely in place. Place valve protection caps where they can be easily found and replaced when cylinders become empty.

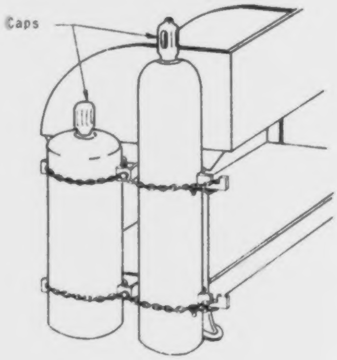

Figure 1. Securing the Cylinders

IMPORTANT SAFETY NOTES:

- Cylinders should always be kept in a vertical position and chained or otherwise secured from falling.
- Do not strike, drop or apply heat to cylinder.
- Valve protection caps should always be in place whenever cylinders are moved or are in storage (full or empty).
- Mark empty cylinders "EMPTY."
- Valves on empty cylinders should be closed completely.
- Empty cylinders should be kept in specified storage areas.

Regulators

1. Inspect the cylinder valve threads for traces of dirt, dust, oil or grease. Remove dirt and dust with clean cloth.

   NOTE: If oil or grease is detected, DO NOT use cylinder. Inform you instructor of this condition immediately.

2. Momentarily open and close (called "cracking") each cylinder valve to dislodge any dirt, dust or rust that may be present.

   CAUTION: Open cylinder valve only slightly. If valve is opened too much, the cylinder could tip over. When "cracking" cylinder valve, do not stand directly in front of valve; stand behind or to one side (see figure 2).

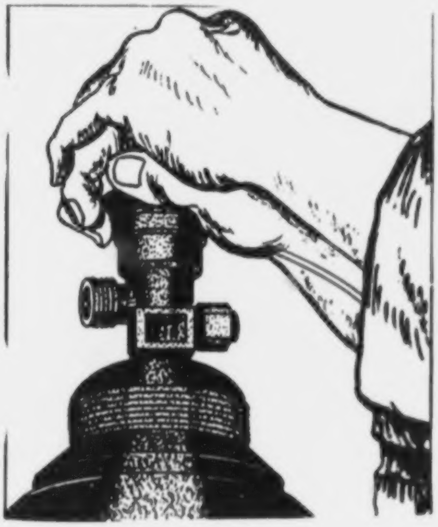

Figure 2. Cracking a Valve

3. Inspect the regulators for damaged threads, dirt, dust, oil or grease. Remove dirt or dust with a clean cloth.

   NOTE: If oil or grease is detected or if threads are damaged, be sure you clean the regulator and/or repair damage before using.

4. Attach the oxygen regulator to the oxygen cylinder valve and tighten securely. Tighten clockwise with proper wrench (see figure 3).

5. Attach fuel gas regulator to the fuel gas cylinder valve and tighten securely. Tighten in direction necessary for the particular fuel gas connection in use.

   NOTE: The oxygen regulator connection has right-hand threads and the acetylene has left-hand threads.

6. Before opening cylinder valves, release tension on the adjusting screws by turning them counderclockwise.

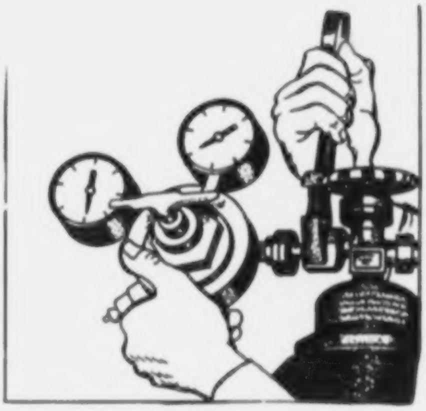

Figure 3. Tightening the Union Nut

Turning on Cylinders

1. Be certain that tension on regulator adjusting screws is released. Stand so the cylinder valve is between you and the regulator.

   NOTE: Never stand in front or in back of a regulator when opening the cylinder valve.

   Slowly and carefully open cylinder valve until maximum pressure is registered on the high-pressure gauge. Now open the oxygen cylinder valve completely to seal the valve packing (see figure 4).

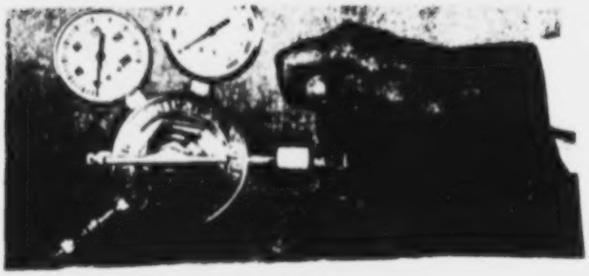

Figure 4

2. Slowly open the fuel gas cylinder valve in the same manner.

   NOTE: Acetylene cylinder valves should never be opened more than one full turn. Other fuel gas cylinder valves should be opened completely.

3. Check for leaks with an approved leak-detector solution. Bubbles will appear if connection is leaking. Regulator connections may be re-tightened.

   CAUTION: NEVER tighten a cylinder valve. If cylinder valve is leaking, place cylinder outdoors and notify your instructor immediately.

4. The use of a reverse-flow check valve on the regulator and torch handle is strongly recommended to reduce the possibility of mixing gases in the hoses and regulators. Mixed gases will burn rapidly once the torch is lighted and can explode in the hoses, regulators or cylinders, resulting in serious damage to the equipment or injury to the operator. To install reverse-flow check valves at the regulators, screw the reverse-flow valves onto the regulator's outlet connection. Tighten securely with the proper wrench.

IMPORTANT SAFETY NOTES:

- Be certain cylinder valves and regulator inlet connections are completely free of dirt, dust, oil or grease.
- If oil or grease is detected on cylinder valves, DO NOT USE! Notify your instructor immediately.
- Never stand directly in front or in back of a regulator when opening the cylinder valve; stand so the cylinder valve is between you and the regulator.
- Always open cylinder valves "slowly" and "carefully."
- Open an acetylene cylinder a maximum of one complete turn.
- Always check for leaks on regulator and cylinder valve connections.

Hose Connections

1. Connect the oxygen hose to the oxygen regulator and tighten the connection firmly with a wrench. Oxygen regulators, check valves and hoses have right-hand threads. Fuel gas regulators, check valves and hoses have left-hand threads (see figure 5).

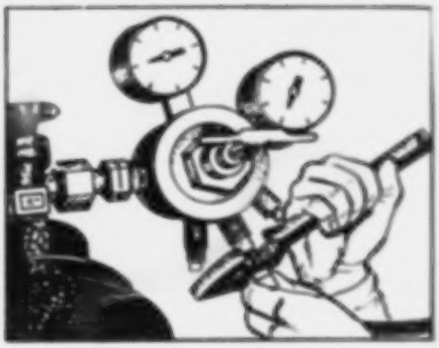

Figure 5. Attaching the Hose

2. Adjust the oxygen regulator to allow 3 to 5 psig to escape through the hose. Allow oxygen to flow 5 to 10 seconds to clear the hose of dust, dirt or preservative; then, shut off the oxygen flow.

   NOTE: New hose preservative talc must be blown out of the hose prior to using the torch.

3. Attach and clear the fuel hose in the same manner.

   NOTE: Be s re to clear hoses in a well-ventilated area--the escaping gases create conditions for fires and explosions!

Welding hoses are exposed to severe abuse. Molten slag and sparkes can come into contact with hoses and burn into the hose exterior. Falling metal in cutting operations can crush or cut into welding hoses. The operator should frequently inspect his hoses and repair damaged areas and, when necessary, replace the hose. Observe the following safety and operating procedures.

IMPORTANT SAFETY NOTES:

- Keep welding hoses clear of any falling metal, slag or sparks.
- Never allow hoses to become coated with oil, grease or dirt. Such coatings could conceal damaged areas.
- Examine the hoses before attaching to welding torch handle or regulators. If cuts, burns, worn areas or damaged fittings are found, repair or replace the hose.

Welding Torch

The welding torch handle is probably the most frequently used item in a welding shop. Since cutting attachments, welding tips and heating nozzles are all connected to the handle, the operator should always protect the handle from possible damage or misuse.

1. Inspect the torch handle head, valves and hose connections for dirt, dust, oil, grease or damaged parts. Remove dirt or dust with a clean cloth.

   CAUTION: DO NOT attach torch handle to the hose if oil or grease is detected or if damaged parts are present. Notify instructor before proceeding.

2. Inspect the welding hose connections in the same manner. Do not use if oil or grease is detected.

3. The use of reverse-flow check valves on the torch handle is strongly recommended to reduce the possibility of mixing gases in the hoses and regulators. Connect the oxygen reverse-flow check valve to the torch handle valve marked "Oxy" and tighten securely with a wrench (right-hand threads). Connect the fuel reverse-flow check valve to the valve marked "fuel" and tighten securely with a wrench (left-hand threads).

4. Attach the welding hose to the reverse-flow check valves and tighten securely (see figure 6).

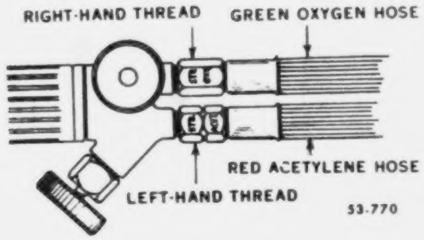

Figure 6. Connecting the Hoses and Torch

### Attaching Welding Tip or Nozzle

1. Inspect the cone end, coupling nut and torch head for damage, dirt, dust, oil or grease. Dirt or dust can be removed with a clean cloth.

   CAUTION: If damage, oil or grease is detected, notify your instructor before proceeding.

2. Inspect the welding tip of nozzle cone end for missing or damaged "O" rings. There must be two "O" rings on the cone end. Damaged or missing "O" rings can allow gases to mix and result in backfires or flashback. Severe damage can result.

3. Inspect the torch head. The tapered seating surfaces must be in good condition. If dents, burns or burned seats are present, the seat must be resurfaced. If the torch is used with poor seating surfaces, backfire or flashback may occur.

4. Connect the welding tip to the welding torch handle and tighten the couling nut using hand pressure only. Wrench tightening may damage "O" rings and create a faulty seal (see figure 7).

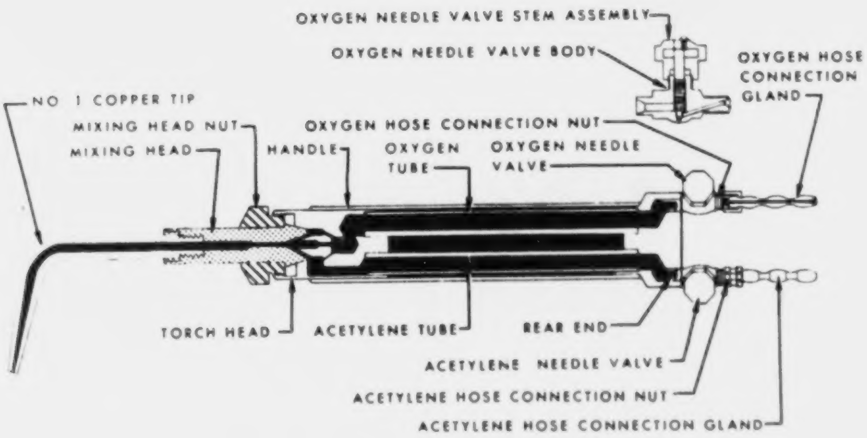
OXYGEN NEEDLE VALVE STEM ASSEMBLY
OXYGEN NEEDLE VALVE BODY
OXYGEN HOSE CONNECTION GLAND
NO 1 COPPER TIP
MIXING HEAD NUT
MIXING HEAD
OXYGEN HOSE CONNECTION NUT
HANDLE
OXYGEN TUBE
OXYGEN NEEDLE VALVE
TORCH HEAD
ACETYLENE TUBE
REAR END
ACETYLENE NEEDLE VALVE
ACETYLENE HOSE CONNECTION NUT
ACETYLENE HOSE CONNECTION GLAND

Figure 7. Oxyacetylene Torch

Setting Up to Weld/Lighting the Torch and Adjusting the Flame

1. Check the thickness of the metals to be welded (figure 8) and prepare as described and illustrated in figure 9.

2. Refer to welding tip selection chart to determine required tip size and regulator pressures for the job (see figure 8).

## OPERATIONAL AND PERFORMANCE DATA

### Oxy-Acetylene Welding Nozzles

| METAL THICKNESS | TIP SIZE | DRILL SIZE | OXYGEN PRESSURE P.S.I.G. | | ACETYLENE PRESSURE P.S.I.G. | | ACETYLENE CONSUMPTION SCFH* | |
|---|---|---|---|---|---|---|---|---|
| | | | MIN. | MAX. | MIN. | MAX. | MIN. | MAX. |
| up to 1/32 | 000 | 75 | 1 | 2 | 1 | 2 | ¾ | 1½ |
| 1/64"-3/64 | 00 | 70 | 1 | 2 | 1 | 2 | 1½ | 2½ |
| 1/32"-5/64" | 0 | 65 | 1 | 3 | 1 | 3 | 2½ | 4 |
| 3/64"-3/32" | 1 | 60 | 2 | 4 | 2 | 4 | 4 | 6 |
| 1/16"-1/8" | 2 | 56 | 3 | 5 | 2 | 5 | 6 | 10 |
| 1/8"-3/16" | 3 | 53 | 4 | 7 | 3 | 6 | 9 | 18 |
| 3/16"-1/4 | 4 | 49 | 5 | 10 | 4 | 7 | 15 | 28 |
| 1/4"-1/2" | 5 | 43 | 6 | 12 | 5 | 8 | 22 | 40 |
| 1/2"-3/4" | 6 | 36 | 7 | 14 | 6 | 9 | 30 | 52 |
| 3/4"-1-1/4" | 7 | 30 | 8 | 16 | 7 | 10 | 38 | 66 |
| 1-1/4"-2" | 8 | 29 | 10 | 19 | 8 | 12 | 48 | 82 |
| 2"-2-1/2" | 9 | 28 | 12 | 22 | 9 | 14 | 58 | 100 |
| 2-1/2"-3" | 10 | 27 | 14 | 24 | 10 | 14 | 70 | 118 |
| 3"-3-1/2" | 11 | 26 | 16 | 26 | 11 | 15 | 84 | 138 |
| 3-1/2"-4" | 12 | 25 | 18 | 28 | 12 | 15 | 100 | 160 |

Gas consumption data is merely for rough estimating purposes. It will vary greatly on the material being welded and the particular skill of the operator.

Pressures are approximate for hose length up to 25 ft. Increase for longer hose lengths about 3 psi per 25 feet.

NOTE: Pressure and consumption data above formulated using 1/4" hose through tip size 8 and 3/8" hose for sizes 9-12. Use 3/8" hose for sizes 9-12.
At no time should the withdrawal rate of acetylene cylinders exceed 1/7 of the cylinder contents per hour.

Figure 8. Welding Tip Selection Chart

3. Open the oxygen valve on the torch handle and adjust the oxygen regulator to the desired delivery range.

4. Close the torch handle oxygen valve.

5. Open the fuel valve on the torch handle in the same manner and adjust the fuel regulator to the required delivery range.

6. Close the torch fuel control valve.

7. Before proceeding to the next step, have your instructor check your work. The complete torch set must be set correctly before lighting off.

Instructor ______________________

8. Wear protective goggles to shield eyes from bright light.

NOTE: The following instructions cover the torch adjustment procedures for acetylene only.

9. Hold the torch in one hand and the spark lighter in the other.

10. Open the torch fuel valve approximately 1/16 to 1/3 turn and ignite the gas.

CAUTION: Point the flame away from persons, the cylinders or any flammable materials.

11. Keep opening the fuel valve until the flame stops smoking and leaves the end of the torch tip about one-eighth inch; then, slightly reduce the fuel supply to bring the flame back to the torch tip (see figure 9).

12. Open the torch oxygen valve until a bright neutral flame is reached (see figure 9).

CAUTION: If you experience a backfire or flashback (a shrill hissing sound when the flame is burning inside the welding nozzle), immediately turn off the acetylene valve; then, turn off the oxygen valve.

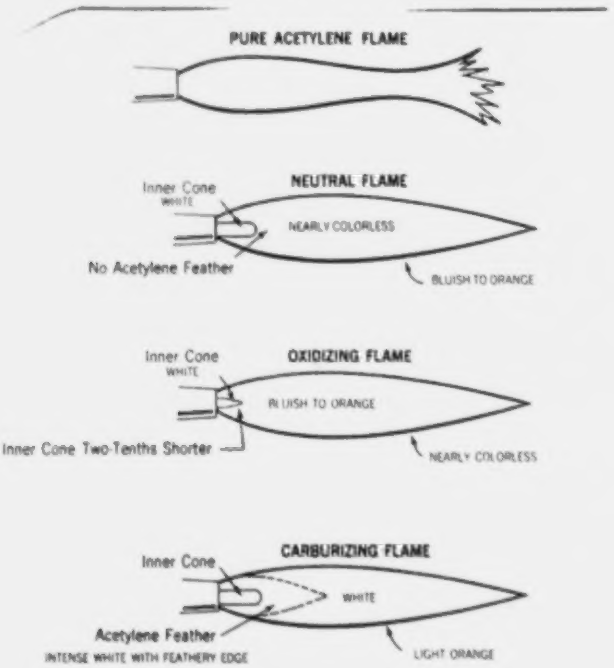
PURE ACETYLENE FLAME
NEUTRAL FLAME
Inner Cone
WHITE
NEARLY COLORLESS
No Acetylene Feather
BLUISH TO ORANGE
OXIDIZING FLAME
Inner Cone
WHITE
BLUISH TO ORANGE
Inner Cone Two-Tenths Shorter
NEARLY COLORLESS
CARBURIZING FLAME
Inner Cone
WHITE
Acetylene Feather
INTENSE WHITE WITH FEATHERY EDGE
LIGHT ORANGE

Figure 9

## Shutting Down the Welding Apparatus

1. Shut off the gases.
   a. First, close the acetylene valve on the torch.
   b. Next, close the oxygen valve on the torch.
   c. Close the acetylene and oxygen cylinder valves.
2. Drain the regulators and hoses by the following procedure.
   a. Open the torch acetylene valve until the gas stops flowing, then close the valve.
   b. Next, open the torch oxygen valve to drain the oxygen regulator and hose. When gas stops flowing, close the valve.
   c. When the above operations are performed properly, both high and low pressure gauges on the acetylene and oxygen regulators will register zero.

## EXERCISE 5

## SILVER SOLDERING

1. Secure enough tubing from the tubing barrel to make six swage connections.
2. After making the swage connections, thoroughly clean the contacting surfaces.
3. Apply a silver soldering flux to the male fitting.
4. Insert the male fitting into the swage and revolve it once or twice to spread the flux evenly.
5. Light the oxyacetylene torch and adjust to a carburizing flame.
6. Apply the flame evenly to one side of the swage, bringing it to a cherry red.

   NOTE: Silver solder melts at a temperature of 1000° to 1150°F.
7. Apply the solder to the top of the fitting on the opposite side from flame while applying heat near the bottom of the swage.

   NOTE: If the heat is applied near the bottom of the swage, the solder will be drawn to the bottom.
8. Turn off the oxyacetylene torch.

   CAUTION: Use pliers to handle hot metal, cool it in water bucket.
9. Cut the completed joint with a hacksaw and check for:
   a. Penetration.
   b. Excess flux.
   c. Oxidation.
   d. Excess solder.
10. Have the instructor check your work. ______________________________

## EXERCISE 6

## OXYACETYLENE WELDING

In oxy-fuel welding, two metals are joined by melting or fusing their adjoining surfaces. This is accomplished by directing an oxy-fuel flame over the metals until a molten puddle is formed. A filler rod may be introduced into the puddle to help the metals form together. In this exercise, you will butt weld with a filler rod. Obtain materials and tools and proceed to welding area.

1. Materials and Tools
   - a. Oxyacetylene Welding Unit
   - b. Welding Tip (#2)
   - c. Gloves
   - d. Welding Safety Glasses
   - e. Pliers
   - f. Wire Brush
   - g. Striker
   - h. Fire Brick
   - i. Two pieces of mild steel strips, 16 gauge 1" by 5"
   - j. Filler rod mild steel
2. PROCEDURES
   - a. Prepare metal for welding
     - (1) Select two pieces of mild steel strips, 16 gauge 1" by 5"
     - (2) Clean metal with wire brush
   - b. Place metal in welding position
     - (1) Arrange fire brick to support the metal
     - (2) Place the metal pieces on top of the fire brick leaving a 1/16" to 1/8" clearance between the metal to allow for expansion
   - c. Insure torch is turned off
   - d. Open tank valves
     - (1) Acetylene
     - (2) Oxygen
   - e. Set working pressure
     - (1) Acetylene - 5 psi
     - (2) Oxygen - 10 psi
   - f. Light torch and adjust to a neutral flame
     - (1) Open acetylene knob on torch 1/8 turn
     - (2) Adjust flame until most of the smoke is gone
     - (3) Open oxygen knob and adjust to neutral flame

NOTE: IF loud blowing noise, adjust acetylene and oxygen knobs down until the blowing sound discontinues.

g. Hold torch in a comfortable, well balanced position

   (1) Right or left hand, whichever applies

   (2) Position filler rod in other hand

   (3) Hold torch and rod between 30° and 45° angle from center

   (4) Place inner cone about 1/16" to 1/8" from metal

h. Tack both edges of the metal

   (1) Keep the torch moving in small circular motions until molten pool begins to form on end of metal

   (2) Add filler rod to pool

   (3) Repeat for other end

i. Laying the bead on the metal

   (1) Place inner cone of flame about 1/16" to 1/8" from surface of base metal

   (2) With small circular motions (about 1/4") form a molten puddle

   (3) Add filler rod to front edge of puddle in front of torch

   (4) Continue the process insuring that the puddle is the same size (1/4") and the weld forms even arc-shaped ripples

   (5) Slowly work the puddle across the metal, 1/16" per ripple, keeping the same size, shape, and centered the entire length of the metal

   (6) Height can be maintained by the amount of filler deposited ( a good weld has 25% more metal than the original metal)

   (7) Speed of travel across metal determines the penetration

j. Turn off oxyacetylene rig

   (1) Turn off torch

   (2) Turn off acetylene tank valve

   (3) Turn off oxygen tank valve

   (4) Open acetylene torch knob - drain hose and regulator

   (5) Open oxygen torch knob - drain hose and regulator

   (6) Close both torch knobs

k Show weld to instructor when completed

Instructor ________________________

# HOT WATER HEATING AND CONTROLS

## OBJECTIVES

Using information given, explain the principles of operation of low/medium temperature hot water boilers by correctly answering 20 out of 25 questions.

Given procedures and trainer, install, operate, and maintain a centrifugal pump with no more than two instructor assists.

## EXERCISE 1

## HOT WATER HEATING AND CONTROLS

Complete the following statements.

1. How is low temperature water usually applied when used for space heating?

2. What is meant by a hot water system that heats directly?

3. What type of hot water heating system is suitable for any size installation?

4. How does a centrifugal pump pump water?

5. Why must a centrifugal pump never be run dry?

6. How often should a centrifugal pump be operated?

7. What should be accomplished on a semiannual inspection of a centrifugal pump?

8. When should wear rings be replaced?

9. How are low temperature hot water boilers classified?

10. What are the types of steel boilers?

11. How many sections are steel boilers constructed in?

12. What is the purpose of the pressure relief valve?

13. What is the purpose of the dip tube on a hot water boiler?

14. What device is added to a hot water boiler to prevent thermal shock?

15. Why should an inlet connection be the same size as the boiler inlet?

16. A ____________ ____________ ____________ prevents gravitational flow of water through the system when the circulating pump is shut off.

17. What is the purpose of the breeching?

18. Why are expansion tanks added to a hot water system?

19. What is the maximum temperature that can be used on an open tank hot water system?

20. Where should an open expansion tank be installed?

21. What is the advantage of using a closed expansion tank over an open tank?

22. What components are added to an open expansion tank?

23. How large must an expansion tank be?

24. How is a closed hot water system automatically supplied with water?

25. At what pressure are pressure regulating valves factory set?

## EXERCISE 2

## Teardown, Reassembly, Installation and Operation of a Centrifugal Pump

1. The instructor will assign you to a centrifugal pump.

2. Insure all valves are closed.

NOTE: Do not use hammers or improper wrenches on this pump.

### Loosening Fittings

1. Use two pipe wrenches (one as a backup) and loosen both unions on the pump piping.

2. Leave unions in place as guides until you are ready to remove casing.

### Removing the Impeller

1. Remove the cap screws holding the casing to the pump frame and remove the casing.

2. Remove the impeller locknut and washer.

3. Slide off the impeller and key.

NOTE: If it is necessary to pry off the impeller, be careful to pry evenly on opposite sides where denting or bending of the impeller shroud will not occur. A tightly stuck impeller will require the use of a wheel or gear puller.

4. Insure all parts are thoroughly clean before reassembling. Check with your instructor before you attempt to re-install your pump parts.

### Stuffing Box Diassembly

1. Loosen the hex nuts.

2. Remove the gland bolts and gland.

3. Inspect the packing. If the packing is frayed or worn, proceed as follows.

4. Pull out the packing rings and seal cage using a packing tool or a rod with a hook on one end.

### Stuffing Box Reassembly

1. Cut two rings of packing (or whatever number is necessary to fill the space below the tapped hole in the stuffing box) so that the packing has a small amount of clearance when it is wrapped around the shaft.

2. Use the gland to push the packing into the stuffing box, staggering the breaks in adjacent packing rings 90 to 180 degrees apart.

3. Slide the seal cage into the stuffing box where it will locate in a position opposite the tapped hole.

4. Continue to fill the stuffing box with packing rings, having the breaks staggered 90 to 180 degrees apart, until there is only enough space for the gland to be started in the bore of the stuffing box.

5. Put the gland, gland clamps and gland bolts in place and tighten the hex nuts enough to compress the packing slightly; then loosen the hex nuts until the gland clears the top packing ring by one-eighth inch.

6. Further adjustment will be made after the pump has been started.

### Impeller and Volute Casing Reassembly

1. Slip the impeller and key onto the shaft.

   NOTE: If a shaft sleeve is used, the key must enter into the slot in the end of the shaft sleeve.

2. Replace the washer and locknut.

3. Replace the gasket using a non-hardening sealing compound, such as grease or graphite.

4. Put the casing in place and fasten securely with cap screws (alternate tightening).

   NOTE: When the pump is located above the liquid level, a foot valve on the end of the suction pipe will retain enough water in the impeller when the pump is shut down to prime it when starting. A gate valve should be installed in the suction line when the liquid is located above the pump.

6. Connect the discharge pipe.

   NOTE: A check valve and gate valve should be installed in the discharge line.

7. Prime the pump, if the liquid level is lower than the pump, by removing the priming plug and fill the suction line and pump.

8. Replace the priming plug prior to starting the pump.

9. Turn the pump over by hand to make sure that it is free and not binding.

10. Check the rotation (rotation shown by the arrow cast on the casing) with a quick start and stop of the pump.

11. Make certain the gate valve in the suction line is fully open and the gate valve in the discharge line is fully closed.

12. Start the motor and, when it is up to full speed, slowly open the discharge gate valve.

    NOTE: Insure pump is turned off before proceeding.

### Packing Gland Adjustment

1. Proceed slowly when tightening the packing gland. Never tighten the gland more than necessary. Never force the packing into a leak-proof position.

2. Tighten the bolts evenly, about one-sixth turn at a time, allowing an interval for the packing to creep into a better sealing position.

3. After you have adjusted the packing gland, the instructor will inspect your work.

### Drive Equipment Accessories

1. Inspect an operating electric motor.

-Circle One-

a. Is there any unusual noise in the motor? YES NO

b. Does the shaft wobble or shake? YES NO

c. Is the motor securely mounted? YES NO

d. Is the motor housing overheated? YES NO

e. Are there any sparks coming out of the motor? YES NO

f. Is the motor dirty with mud, grease, rag lint or leaves and grass? YES NO

g. Does the motor have an oiling hole or grease zert? YES NO

h. Is there exposed or naked wire? YES NO

2. Inspect the coupling between the motor and the pump.

a. What absorbs the shock of starting and pumping variations?

______________________________________________

b. What wrench is needed to loosen this coupling from the shaft?

______________________________________________

Unit Failure

If the unit fails, use the following troubleshooting guide.

TROUBLESHOOTING GUIDE

| PROBABLE CAUSE | REMEDY |
|---|---|
| FAILURE TO DELIVER WATER, OR SUFFICIENT WATER AND SUFFICIENT PRESSURE | |
| Pump not primed. | Reprime. |
| Pump not up to speed. | Check for incorrect motor voltage and motor overload. |
| Discharge head beyond pump shutoff. | Alter installation or provide pump suitable for higher pressure. |
| Excessive suction lift. | Reduce lift: use larger suction pipe. |
| Incorrect direction of rotation. | Reverse rotation. |
| Insufficient positive head on suction for hot liquids. | Give pump more submergence, simplify and increase size of suction piping. |
| Footvalve too small. | Replace with adequate size footvalve. |
| Strainer clogged. | Clean out. |
| Worn wearing ring or damaged impeller. | Recondition or replace worn parts. |
| High spot or air pocket in suction line. | Repipe to pump suction to eliminate loose and high spots. |
| PUMP LOSES PRIME AFTER STARTING | |
| Excess suction lift. | Reduce lift: use larger suction pipe. |
| Air leaks in suction line. | Check joints, make up tight with pipe joint compound. |

## EXERCISE 2

Complete the following statements:

1. What should be the first step in shutting down a hot water boiler?

2. How long should water circulation be maintained through the boiler when shutting the unit down?

3. When flushing a hot water boiler, how long should fresh water be run through the boiler?

4. What would be the first procedure to follow when filling a hot water system?

5. How much water should be added to the expansion tank when filling the system?

6. When should you begin venting air from a hot water system?

7. Why is it necessary to drain and refill the system several times before starting the fire for initial operation?

8. When performing a preoperational inspection, the piping system should be checked for ______________________________________________
______________________________________________________________
______________________________________________________________.

9. Why should a newly filled system be heated to a higher temperature than anticipated for normal operations?

10. What procedure should be accomplished on a newly installed system after two days of operation?

11. How often should a hot water system that has been flushed and vented be drained?

12. What will a stoppage in the system cause?

13. What will happen if the water temperature gets too high?

14. What can happen if the water temperature gets too high?

15. If the system pressure fluctuates or pulsates rapidly, what should you check?

STUDY GUIDES

J3ABR54532 001-VI-1 thru VI-3

Technical Training

# Heating Systems Specialist

# CENTRAL PLANT AND HIGH TEMPERATURE HEATING SYSTEMS

February 1984

3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

DESIGNED FOR ATC COURSE USE
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ATC FORM 214 (JAN 76) OBSOLETES ATC FORMS 214, MAY 69, 522, NOV 63 AND 523, MAY 71. STANDARD COVERSHEET

This study guide was designed to guide you through your study assignments in the most logical sequence for easy understanding. The supplementary information section contains additional material required to keep you up to date in this subject. Answer the self-evaluation questions so you will better understand and retain the material you have studied.

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This publication supersedes SGs J3ABR54532 001-VI-1 thru VI-3, dated April 1983. (Copies of superseded publications may be utilized until supply is exhausted.)

## EXPLANATION OF TERMS

ABNORMAL--Not normal.

ABSORBENT--Ability to soak up.

ACCESS--Permission or ability to enter.

ACCUMULATIONS--Collections.

ADHERING--Sticking.

ADJOINING--Next to, beside.

ADJUST--Regulate.

ADJUSTMENT--To regulate.

AFFECTING--To influence.

ALIGNMENT--Putting into precise position.

ALLOY--Mixture of base metals.

ALTERNATING--Changing back and forth.

ANNUALLY--Once a year.

APPROACHES--Entries, getting closer.

APPROPRIATE--Right or correct.

APPROXIMATELY--About, almost, close.

ARRANGEMENT--Having been put in order.

ASBESTOS--A fire resistant material.

ASSEMBLED--Collected, put together.

ATMOSPHERE--Air

AUTHORIZED--Officially allowed.

AUTOMATIC--Self acting.

AUXILIARY EQUIPMENT--Extra equipment necessary.

AVAILABILITY--To have close to use.

BAFFLES--Used to direct flow of gases, steam or water.

BASICALLY--Fundamental.

BELLOWS--Expandable device used in traps, valves and controls.

BIMETALLIC--Composed of two different metals.

BLOW--To send a current of air.

BLOWDOWN--Discharge, drain partially.

BLOWER--Fan.

BLOWING--Act of moving air.

BLOW OFF--Blowdown.

BODY--The main part.

BOIL--To heat to the boiling point.

BOILER--Enclosed vessel used to generate steam.

BREECHING- dottom of a pulley block.

BRICKWORK--Work of or with brick.

BURNER--Part of boiler which produces flame.

BYPASS--To go around.

CALIBRATE/CALIBRATION--Find, change or mark of graduation.

CAM-ACTUATED--Operated or controlled by a cam.

CAPABLE--Able to.

CAPACITY--Measure of content, maximum output.

CAPILLARY--Small bore tube used to transmit pressure.

CASING--Body.

CASTABLE--Able to be molded.

CAULKED--Stopped up, sealed against leakage.

CENTRIFUGAL--Going to acting in a direction away from a center or axis.

CERTIFIED--Authorized by a certificate.

CHAMBER--Cavity or compartment.

CHARACTERISTICS--Traits, qualities or properties.

CIRCULATE--To move.

CIRCULATION--The movement of.

CIRCULATOR--That which causes to circulate.

CLASSIFIED--Divided into classes.

CLINKERS--Stony matter fused together.

COMBINATION--Two or more.

COMBUSTION--Burning.

COMMERCIAL--Used for or by business.

COMMUNICATION--Exchange or express thought, ideas, opinions or feelings.

COMPENSATE--Make up for.

COMPONENTS--Parts of.

COMPRESSION--Squeezing or compacting with power.

CONDENSATE/CONDENSE--Steam turned back into water.

CONDITIONS--Provisions or working status.

CONDUCTIVITY--Degree of ability to transmit electricity.

CONDUIT--Tube in which pipes or wires are run.

CONNECTED/CONNECTION--Attach to.

CONSISTENCY--Thickness.

CONSTANT--Always or lasting.

CONSTRUCTION--Made or made of.

CONSUMER/CONSUMING--User, using.

CONTACTS--Electrical touching points.

CONTINUOUS--Always or lasting.

CONTRACTION--Shrinkage.

CONTROL--Having power over.

CONVERTERS--Device used to change heating mediums (i.e., steam to water).

CORRESPONDING--To be equivalent or parallel.

CORROSION--Act of eating away by degrees.

CYCLE--A sequence of a recurring succession of events.

DAILY--Once a day.

DAMAGE--Destroy or destruction.

DAMPERS--A plate used for regulating the flow of air or gases.

DEAERATE/DEAERATING/DEAERATION--Removal of air from water.

DEAERATOR--Device used to deaerate with.

DECREASE--To lesson or make smaller.

DEFECTIVE--Not as it should be.

DEMAND--Requirement.

DEPOSITS--Collections of.

DESIGN--Plan or purpose.

DESIGNATED--Picked or chosen.

DIAGRAMS--Simplified drawings.

DIAMETER--A straight line through the center of a circle.

DIAPHRAGM--Thin membrane divider or partition.

DIFFERENCE--Sum of subtraction.

DILUTION--Act of reducing strength.

DIMENSIONS--Measurements of an object's shape.

DISCHARGE/DISCHARGED--Remove, throw out.

DISCUSS--Talk about.

DISMANTLE--Take apart.

DISSOLVE--To cause to disperse or pass into solution.

DISTRIBUTED/DISTRIBUTION--Convey, give out or supply portions of.

DOWNWARD--From a higher place to a lower.

ECONOMIZER--Closed feedwater heater using hot stack gases as a heating medium.

EFFICIENCY/EFFICIENT--Measurement of operation or ability.

ELECTRICAL--Pertaining to electricity.

ELECTRONIC--Pertaining to electronics.

ELEMENT--A part or piece of.

EMERGENCY--Pressing need calling for immediate action.

EQUALIZE--To make equal.

EQUILIBRIUM--Balance.

EQUIPMENT--Implements used in an operation or activity.

ESTABLISHED--Instituted, recognized.

EVALUATE--To examine and judge.

EXCESSIVE--Going beyond a limit.

EXHAUST--Already used once.

EXPAND/EXPANDED/EXPANSION--Increase in size or volume.

EXPLOSIONS--Violent outbursts.

EXPOSED--Uncovered or unprotected.

EXTERNAL--Outside.

EXTREME--Maximum.

FACILITIES--Something built, installed or established to serve a purpose.

FAILURE--Falling short.

FEATURE--A special attraction.

FEEDWATER--All water put or to be put into a boiler.

FIREBOX--Chamber that contains a fire.

FIREBRICK--Used to build furnace refractories.

FITTINGS--Various controlling devices installed on a boiler.

FLASHING--Rapid conversion of hot water to steam due to a pressure drop.

FLEXIBLE--Bendable or pliable.

FLUCTUATION--Changing from a norm.

FORCED--Done or produced with effort.

FROST LINE--Depth to which the ground freezes.

FUNCTION/FUNCTIONING--Work, perform.

FURNACE--Where initial combustion and burning of fuel takes place.

FUSIBLE PLUG--Brass plug with tin core, used as a low water alarm.

GASES--Mixture of carbon and oxygen produced and given off in the burning process.

GASKET--A ring of material fitted tightly around a joint to keep it from leaking.

GENERATE/GENERATED--To make or produce.

GRADUATED--Marked with degrees of measurement.

GRAVITY--Force that draws objects toward the center of the earth.

HAND-HOLE--Hand sized orifice in a boiler to facilitate maintenance.

HARMFUL--Damaging, injurious.

HEADER--Pipe or tube shared by two or more boilers, objects or devices.

HEATING--The act of increasing the temperature.

HORIZONTAL--Parallel to the horizon.

HYDRAULIC--Operated, moved or effected by a liquid; i.e., water or oil.

HYDROSTATIC TEST--Filling boiler with water to a pressure one and one-half times the safety valve setting.

IGNITION--Act of setting on fire.

ILLUSTRATED/ILLUSTRATES--Drawn, pictured or shown.

IMPINGEMENT--Encroachment or infringement.

IMPORTANT--Having much meaning or value.

IMPRACTICAL--Not practical.

INADEQUATE--Not enough or not good enough.

INCHES--Units of measurement equalling 1/12 of a foot.

INCORPORATE--Unite.

INCREASE--Add to.

INDEFINITELY--Unknown amount of time.

INDEPENDENT--Not depending on.

INDICATE/INDICATING--Point, direct or show.

INDUCED--Sucked up, brought on.

INDUSTRIAL--Relating to industry.

INFORMATION--Communication of knowledge.

INJECTOR--A unit to force water into a boiler.

INLET--Entry.

INSPECT/INSPECTION--To check or look carefully.

INSTALL/INSTALLED--To set up for use.

INSTALLATION--Air Force bases or properties which contain heating equipment.

INSTRUCTIONS--Procedures.

INSULATE/INSULATION--Protect or cover.

INTELLIGENT--Able to understand.

INTEGRATE/INTEGRATED--Mix together.

INTERFERE--To hinder.

INTERMITTENT--Coming and going at intervals.

INTERNAL--Inside.

INVERTED--Upside down.

IRRESPECTIVE--Without regard.

ISOLATING VALVE--Valve used to separate a device from the main flow.

JURISDICTION--Control or authority over.

LAMINATIONS--Layers of bonded materials.

LATTER--Relating to the last or more recent.

LETHAL--Deadly.

LIMITATIONS--Limits.

LINKAGE--System of bars, rods or links.

LINTEL--Threshold.

LOCATED/LOCATION--Indicates place or site.

LONGITUDINAL--Placed or running lengthwise.

LUBRICATE/LUBRICATED/LUBRICATION--To make slippery, usually with grease or oil.

MAGNESIUM--A form or type of insulation.

MAINTAIN--To keep in existing state.

MAINTENANCE--To service or repair a piece of equipment.

MALFUNCTION--Failure to operate normally.

MANUAL/MANUALLY--Worked by hand.

MANUFACTURER--Maker.

MASONRY--To do with stone.

MAXIMUM--Most or highest limit.

MECHANICAL--Operated by a machine.

MECHANISM--Mechanical operation or action.

METER--Indicating type measuring device.

METHOD--Way of doing.

MINIMUM--Least or lowest limit.

MISALIGNMENT--Not aligned.

MIXTURE--State of being mixed.

MOISTURE--Wetness.

MONTHLY--Once a month.

MORTAR--Mixture of cement of lime with sand and water to hold bricks together.

MOVEMENT--Change of place, position or posture.

MUNICIPAL--Relating to local government.

NECESSARY--Needed.

NIPPLE--Short piece of pipe.

NONCONDENSABLE--Unable to be condensed.

NON-RETURN VALVE--Valve permitting flow only in one direction.

NORMAL--Average.

OBSERVATION--Watching.

OBTAINED--Got or received.

OPERATE/OPERATING/OPERATION/OPERATIONAL--Relating to work.

OPERATOR--One who operates.

OPTIMUM--Best.

ORIFICE--Hole or opening.

OUTLET--Exit.

OXYGEN--A gas without color, taste or odor, and is a chemical element ($O_2$).

PACKAGE--Moderate sized unit with all essentials.

PASSAGE--Channel, course, tunnel or corridor.

PENETRATE--Pass into or through.

PERCENT--Reckoned on the basis of a whole divided equally into one hundred parts.

PERFORATIONS--Holes.

PERFORM--Do.

PERIODICALLY--Fixed intervals between set times.

PERMANENT--Fixed or lasting.

PERMISSIBLE--Allowed.

PERSONNEL--People of a unit or group.

PISTON--A sliding piece moved by or moving against a liquid or gas.

PLASTIC FIREBRICK--Unburned brick that can be shaped to form refractory linings.

PNEUMATIC--Operated by air.

POSITION--Place or posture.

POSITIVE DISPLACEMENT--Equal reaction to an action.

POUNDS--Unit of weight measurement equaling 16 ounces.

PRECAUTION--To be on one's guard.

PREFABRICATED--Already made.

PREHEATERS--Equipment used to heat something before it is used.

PRELIMINARY--Something that precedes.

PREOPERATION/PREOPERATIONAL--Before operating.

PRESSURE--Force exerted.

PREVENT/PREVENTING--To stop from happening.

PRIMARY--Main.

PRIMING--Filling with water.

PRINCIPAL--Most important.

PROCEDURE--Steps followed in a definite order.

PROGRAMMER--Controlling device used on boilers.

PROJECTING--Going beyond.

PROLONGED--To lengthen the time of.

PROPER--Right or correct.

PROTECTION--Guard against.

PROVIDE--To supply or support.

QUALIFIED--Complied with the specific requirements.

QUALITIES--Peculiar and essential characteristics.

QUARTERLY--Four times a year, three months or 90 days.

QUESTIONABLE--Doubtful.

RECOMMEND--To attract favor to.

RECTIFICATION/RECTIFYING--To make unidirectional.

REDUCE/REDUCING/REDUCTION--Decrease or make smaller.

REFRACTORY--Heat resisting nonmetallic ceramic material.

REGENERATIVE--Ability to form or create again.

REGULATE/REGULATING/REGULATOR--To control the flow of.

RELAY--Electrical device used to delay the flow of current.

REMOVED--Taken away from.

REPAIR--Fix or put back into condition.

REPLACE/REPLACEMENT--Substitute.

REQUIRE/REQUIRED/REQUIREMENTS--Needed or essential.

RESIDUE--Remains of.

RESISTANCE--Opposition against.

RESPIRATORY--Breathing.

REVOLVING--Turning around on an axis.

RIVETED--Fastened or united with rivets.

ROTATION--The turning of a body on an axis.

SAFETY--Condition of being safe from or causing hurt, injury or loss.

SCANNER--Control component used to sense flame.

SEDIMENT--Settlings of impurities.

SEQUENCE--The order of progression.

SETTING(S)--Material that covers an inside surface of a boiler furnace.

SHALLOW--Opposite of deep.

SHRINKAGE--Amount of decrease in size.

SIMULTANEOUSLY--At the same time.

SOLUTION--Liquid containing a dissolved substance.

SPALLED/SPALLING--The flaking and chipping of brick surfaces.

SPECIFICATIONS/SPECIFIED--Detailed precise presentation of something.

STANDARD--Something established as a rule for measuring quantity, weight, extent, value or quality.

STATIONARY--Fixed, immobile.

SUFFICIENT/SUFFICIENCY--Enough.

SUPERHEATER--Tubes in steam boilers that add extra heat to the steam before exiting the boiler.

SUPERVISOR--Administrator in charge of.

SUSPENDED--To maintain from falling or sinking.

SYSTEM(S)--Regularly interacting or interdependent group forming a unified whole.

TAPERED--Becoming gradually smaller toward one end.

TEMPERATURE--A measurement of heat in degrees Fahrenheit or Celsius.

THERMODYNAMIC--A steam trap operated by the dynamics of heat.

THERMOHYDRAULIC--A feedwater regulator operated by expansion and contraction of water.

THERMOSTATIC--A feedwater regulator operated by the expansion and contraction.

THICKNESS--Measurement from one side through to the other.

THOROUGHLY--Completely.

THROTTLING--To prevent or check activity of.

TURBINE--Rotary engine actuated by the reaction or impulse of a current of fluid or gas.

TYPICAL--Common.

UNCONDENSED--Non condensed.

UPWARD--From lower to higher.

VACUUM--Devoid of matter.

VALVE--Mechanical device used to stop or permit the flow of fluids or gases.

VENTILATE/VENTILATION--To air out.

VERIFICATION--Act or process of confirming.

VERTICAL--In an upright or up-and-down motion or position.

VIBRATION--Periodic motion in alternately opposite directions.

VOLTAGE--Unit of electrical potential or potential difference.

WATER--Contains two parts hydrogen and one part oxygen, expressed as $H_2O$.

WATER COLUMN--A steam boiler external fitting used to prevent fluctuations of water in the gauge glass.

WITHDRAWING--Taking out or away.

YEARLY--Once a year.

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# THEORY OF OPERATION AND CONSTRUCTION OF STEAM HEATING SYSTEMS

## OBJECTIVES

Given information, identify principles concerning theory of operation and construction features of steam heating systems with 70% accuracy.

Given information, identify the procedures for removing and installing boilers with 70% accuracy.

Given information, identify basic facts about components of feedwater system with 70% accuracy.

Given information, determine procedures for installation, operation and maintenance of reciprocating pumps with 80% accuracy.

Given information, determine step-by-step procedures for operating and servicing pressure/temperature recording equipment with 80% accuracy.

Given information, operate and service draft indicating and regulating equipment with instructor assistance.

Given information, perform service of flow meters and recorders with instructor assistance.

Given information, troubleshoot boiler flame control system with instructor assistance.

## INTRODUCTION

You will want to do your best as a heating systems specialist. You will be interested in the information in this block. What you learn here may save your boiler and your life.

## INFORMATION

### CENTRAL HEATING PLANTS

A central heating plant is an assembly of coordinated equipment used to supply the heat needed to meet job requirements. Heat is generally delivered as hot water or steam and is used to warm buildings or groups of buildings and to supply hot water and steam to hospitals, laundries, dining halls, dry cleaning plants and industrial installations.

There are two main types of central heating plants: the high temperature water (HTW) plant which produces hot water for heating and the steam plant which produces steam to supply the required heat.

Steam plants are the most common types of plants used in the Air Force. To discuss steam plants we must first find out what steam is.

### FUNDAMENTALS OF STEAM GENERATION

To acquaint you with some of the fundamentals of the process of steam generation, suppose that you set an open pan of water on the stove and turn on the heat. You will find that the heat causes the temperature of the water to increase and, at the same time, to expand in volume. When the temperature reaches the BOILING POINT (212°F, or 100°C, at sea level) a change occurs in the water; the water starts vaporizing. If you hold the temperature at boiling point long enough, the water will continue to vaporize until the pan is dry. Now a point to remember is: THE TEMPERATURE OF WATER WILL NOT INCREASE BEYOND THE BOILING POINT. Even if you add more heat after the water starts to boil, the water will not get any hotter, as long as it stays at the same pressure.

But, suppose you place a close-fitting lid on the pan of boiling water. The lid prevents the steam escaping from the pan, and this results in a buildup of pressure inside the pan. However, if an opening is made in the lid, steam will escape at the same rate it is generated. As long as any water remains in the pan, and as long as the pressure remains constant, the temperature of the water and steam will remain constant and equal.

The steam boiler operates on the same basic principle as a closed container of boiling water. By way of comparison, it is true with the boiler as with the closed container, that steam formed in boiling tends to push against the water and sides of the vessel. Because of this downward pressure on the surface of the water, a temperature IN EXCESS of 212°F is required for boiling. The higher temperature is obtained simply by increasing the supply of heat. Bear in mind, therefore, that: AN INCREASE IN PRESSURE MEANS AN INCREASE IN BOILING POINT TEMPERATURE.

It is simple to determine the temperature of the water once you know the steam pressure. First, you determine the square root of the steam pressure; then multiply this by 14 and add the constant number of 198. For example, when the steam pressure is 100 pounds per square inch of the gauge (psig), the square root is 10. When 10 is applied to the formula, the water temperature is 338°F. (10 x 14 + 198 = 338).

The basic principle of boiler operation and construction features are facts that you, as a heating specialist, must understand since the boiler is the main unit of the central steam plant.

## BOILER CONSTRUCTION FEATURES

The boiler is the main unit of a central steam plant. Every other piece of equipment is subordinated to the boiler and its function of boiling water at the required pressure to produce steam. A boiler is composed essentially of two main parts; the furnace in which fuel-combustion takes place, and the pressure parts which contain water and/or steam. Figure 1 illustrates a cutaway view of a boiler showing furnace, pressure parts, feedwater inlet, steam outlet, etc.

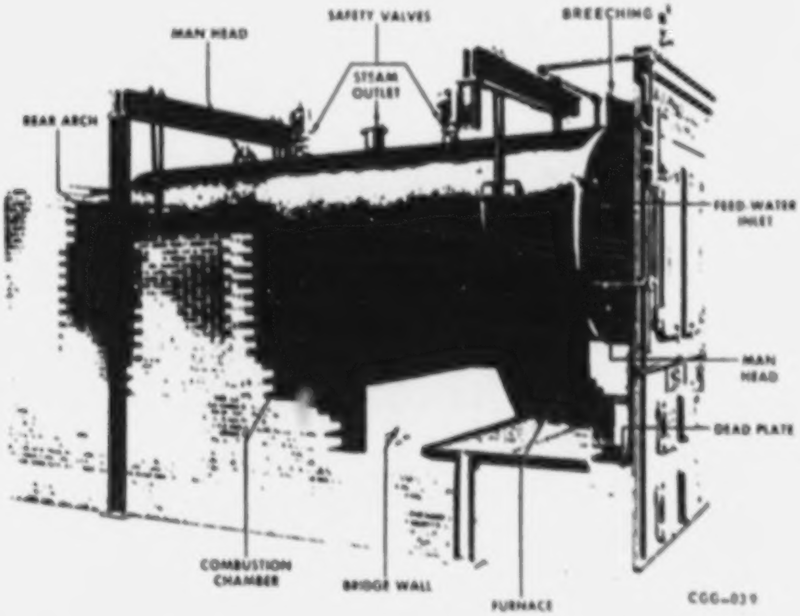


Figure 1. Horizontal Return Tubular Firetube Boiler

### Furnace Construction

Furnace design is important for the efficient combustion of a fuel. Its volume (combustion space) determines the time available for complete combustion; its shape can help promote turbulence.

Some furnaces have refractory arches and/or bridges that reflect heat and maintain a high temperature in specific zones. The heat release in BTUs per cubic foot of furnace volume must be kept with economical limits. These limits depend on the nature of the furnace setting (enclosing walls), boiler heating surfaces exposed to radiant heat, nature of the fuel, and type of firing.

Furnace settings may consist of all solid refractor walls, refractory air-cooled walls, a combination of refractory and water-cooled walls, and water walls when the boiler heating surface form the entire furnace wall. High temperature adversely affects refractory materials; therefore, refractory-wall furnaces are limited to operations in which low heat is released.

Pressure Parts

Pressure parts are the totally enclosed metallic sections, compartments, or tubes which contain steam or water. They must be strong enough to withstand continuously the maximum pressure and temperature for which the boiler is designed. These sections comprise the drums, headers, waterboxes, tubes and waterwalls.

Tubes and drums are used as the principle pressure parts largely because of their ease of manufacture and the characteristic of a cylinder as such that it has maximum strength for minimum material thickness. Tubes can be bent readily and arranged in groups which give effective heat absorption and minimum cost.

DRUMS. Boiler drums are divided into two types: steam drums and mud drums.

STEAM DRUMS. The steam drum is always located at the top of the boiler. It is cylindrical in shape, and (except in some heater-type boilers) it runs from the front of the boiler to the back. The steam drum provides a space for the accumulation of steam generated in the tubes and for the separation of moisture from the steam and it serves as a storage space for boiler water, which is distributed from the steam drum to the downcomer tubes. (In normal operation, the steam drum is kept about half full of water.) In addition to these basic functions, the steam drum either contains or is connected to many of the important controls and fittings required for the operation of the boiler. (See figure 2.)

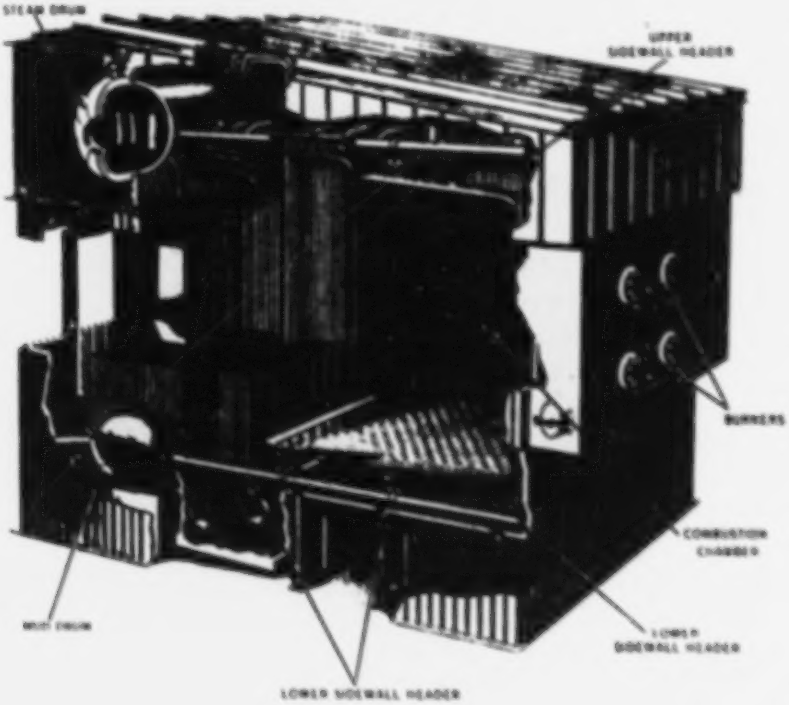


Figure 2. Water Tube Boiler

MUD DRUMS. The mud drums equalize the distribution of water to the generating tubes and provide a place for the collection of loose scale and other solid matter in the water. This sediment is removed from the mud drums by periodic operation of the bottom-blowdown valves. Mud drums are cylindrical in shape and considerably smaller than the steam drums. (Figure 2)

TUBES. Water tubes are always designated by outside diameter. Most water tube boilers fall within this range. In fire tube boilers, tubes are designated by inside diameter.

Boiler tubes are installed with ends projecting twice the tube wall thickness through the tube sheets. Projecting ends are flared slightly in water tube boilers and are left that way because they are surrounded by water or steam. Since tube ends of a fire tube boiler are surrounded by hot gases, they would soon burn off if allowed to project. Therefore, they are beaded and hammered until they are flat against the tube sheet. The process also increases the holding power of the tube.

HEADERS. Headers are used in waterwall construction to connect groups of tubes. They are usually formed of heavy wall tubing or pipe, but may be forged. Figure 3 illustrates some typical header types. Headers are divided into two groups, box and sectional.

Sectional. A hand hold opposite the end of each tube permits installation, cleaning and inspection. Each section is connected to the steam drum by expanded and flared tubes. A mud drum is connected by short nipples to the bottom of each of the rear header sections.

Box. Box-headers are like sectional headers except that two flat boxlike headers replace the individual sectional headers. These boxes are made up of steel plates into which the tubes are expanded.

Internal Fittings (Figure 4)

INTERNAL FEED PIPE (Figure 4). The internal feed pipe runs the full length of the stam drum. It is installed in the water space near, but not touching, the bottom of the drum. One end of the internal feed pipe connects through either the front or the rear drum head from the boiler feed line; the other end is blanked off. The feed water flows from the feedwater heater into the feed water pipe, and is distributed evenly throughout the drum by way of holes in the feed pipe. These holes are drilled along the entire length of the feed pipe; they are on the upper side only, so that the feed water discharges upward rather than downward. This arrangement has two main advantages:

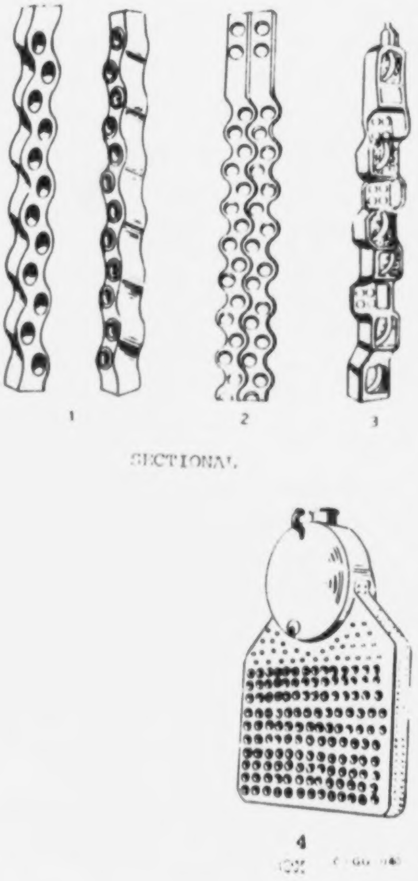


Figure 3. Headers

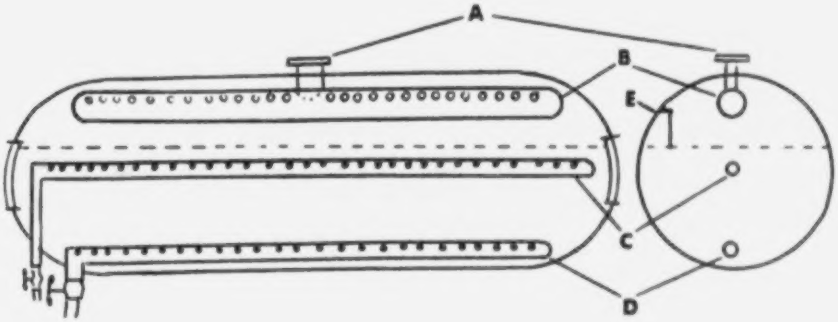
--- The incoming feed water causes the least possible interference with the natural circulation of water in the boiler when it discharges upward.

--- The relatively cool incoming water is directed away from the hot steam drum metal, in order to reduce the possibility of setting up metal stress.

SURFACE BLOW LINE (Figure 4) The surface blow line is a perforated pipe which, like the internal feed pipe, extends the full length of the steam drum. It is located about half an inch below the normal water level. The holes in the line are located along the upper side only.

The surface blow line is used to remove grease, scum, and light solids from the boiler water. One end of the line is blanked off, the other is connected through the drum to the surface blow valve. In some older types of boilers, a shallow scum pan is attached to the surface blow line.

DRY PIPE (Figure 4). The dry pipe is a steel pipe about 5 or 6 inches in diameter. It is installed along the centerline of the steam drum, and runs almost the entire length of the drum. Both ends of the dry pipe are closed. Steam enters by way of holes or slits which are cut along the entire length of the upper surface. The perforations are made in the upper surface only, so that the steam must make a sudden change of direction in order to enter the dry pipe. Some moisture is lost when the steam changes direction; so the dry pipe is, in effect, a steam separator. The steam leaves the dry pipe through the main steam outlet.



A — STEAM OUTLET
B — DRY PIPE
C — SURFACE BLOW OFF PIPE
D — INTERNAL FEEDWATER PIPE
E — STEAM BAFFLE

Figure 4. Cross Sections Showing Internal Fittings

### Stays

Flat surfaces of a boiler are held in place by braces, which are called stays. The most important types of stays are the gusset, diagonal, through, sling, and staybolts.

GUSSET (Figure 5). The gusset stay consists of one or two angles fastened to each of the stay surfaces and connected by a steel plate. They are very rigid and sometimes cause undue stress.

DIAGONAL (Figure 6). Diagonal stays are normally made of round iron flattened on one end and T-shaped on the other. The T-shaped end is riveted to the flat surface to be supported and the other end is riveted to the shell.

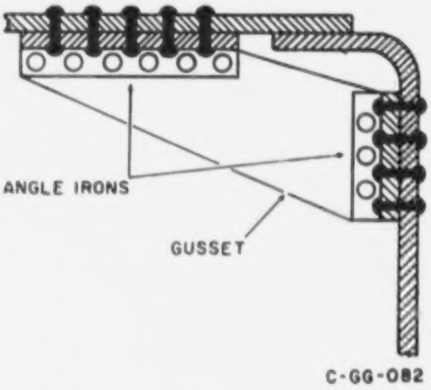


Figure 5. Gusset Stay

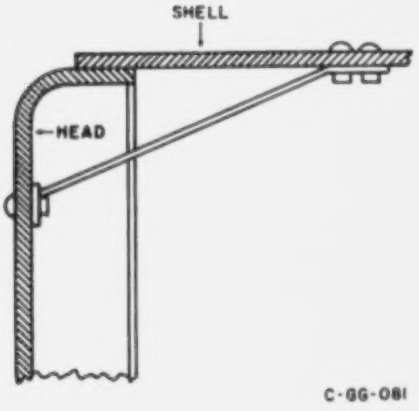


Figure 6. Diagonal Stay

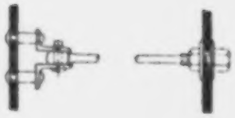


Figure 7. Through Stay, Showing Two Methods of Fastening to Shell

THROUGH STAYS (Figure 7). Through stays extend from one flat surface to another. One type is threaded and fitted with two nuts and a large washer on each end. Another type is threaded on one end; the other end is supported by a pin connection to two angles riveted to the head. To permit water circulation between the head and angles, they are separated with spacers.

SLINGSTAYS (Figure 8). Slingstays and radial stays are similar. They have a pin joint at one or both ends to permit a slight movement of the stayed sheets.

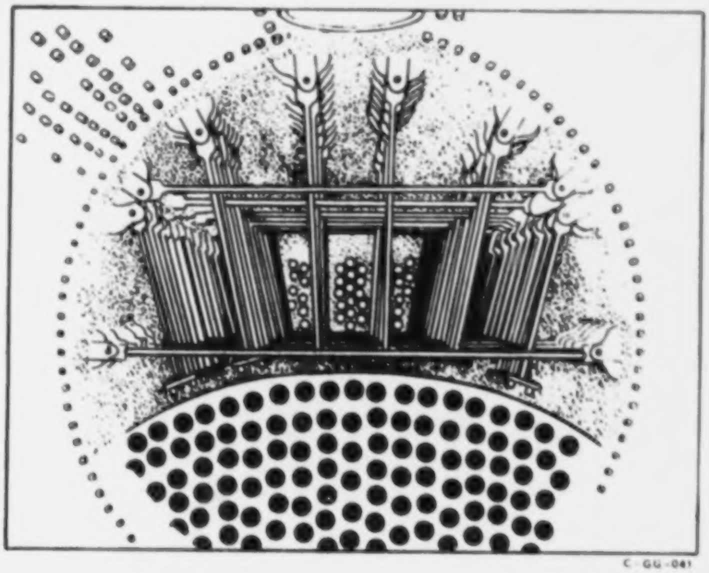


Figure 8. Inside of 300 HP 150 psi Firebox Boiler, Showing Slingstay Bracing of Crown and Wrapper Sheet

STAYBOLTS (Figure 9). Staybolts are short through stays which are threaded through the tube sheets and riveted at the ends. A 3/16 inch diameter telltale hole is drilled in each end of the staybolt: Leakage from the hole indicates a broken staybolt. The holes may be drilled to at least 1/2 inch beyond the inside of the plate, or all the way through the bolt. If the staybolt is over 8 inches, it need not be drilled.

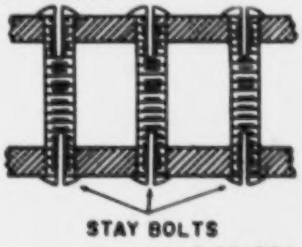


Figure 9. Staybolts

### Baffles

Baffles may be broken down into two different types depending on their location and use. The two types are: gas baffles and steam baffles.

GAS BAFFLES. Gas baffles are thin walls or partitions used to direct the combustion gases over the heating surfaces with minimum draft loss and maximum heat absorption. They may be constructed of either refractory material or metal. Steel gas baffles are used in low temperature zones; refractory baffles, supported and cooled by the tubes, are used in high temperature zones. (See figure 10.)

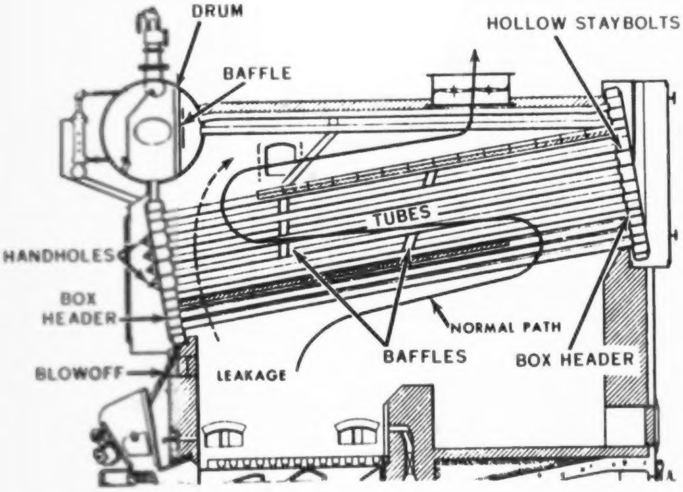


Figure 10. Cross Section of Box-Header

STEAM BAFFLES. Steam baffles may be installed inside the steam drum in order to direct the flow of steam or water, ensure adequate circulation throughout the drum, and prevent violent agitation of the water. Most steam baffles are removable.

### Stacks and Breechings

Stacks are necessary for discharging the products of combustion at an elevation high enough to comply with health requirements, and to prevent nuisance due to low flying smoke, soot, and ash. A boiler needs draft to mix air correctly with the fuel supply, and to conduct the flue gases through the complete setting.

The air necessary for combustion of fuel cannot be supplied normally by natural draft, therefore, draft fans may be used to ensure that the air requirements are properly met. Three types of draft systems used on boilers are forced-draft, induced draft and balanced draft.

The forced-draft fan forces air through the fuel bed, or fuel burner, and into the furnace to supply air for combustion.

The induced-draft fan draws gases through the setting, thus ensuring their removal through the stack. Balanced draft is a combination of forced and induced draft systems.

BREECHINGS. Breechings are used to connect the boiler to the stack. They are usually made of sheet steel, with provisions for expansion and contraction. (Figure 11.)

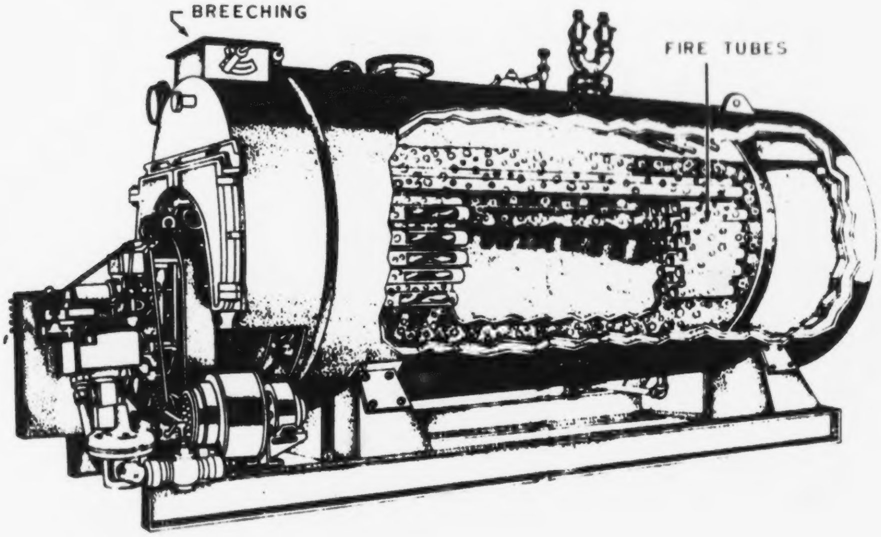


Figure 11. Scotch Type Package Unit Boiler

## TYPES OF BOILERS

Steam boilers may be made of cast iron or steel and are normally further classified into two general types: fire tube and water tube.

### Fire-Tube Boilers

The fire-tube boiler's tubes are filled with hot gases and surrounded by water. Fire tube steam boilers are easier to operate and cheaper than water tube boilers. They can also use a lower quality of feedwater. However, design limitations restrict their use to relatively small capacity. There are many types of fire-tube boilers. They are internally fired when the furnace or firebox is totally or partly surrounded by water, as in the Scotch Marine illustrated in figure 11. They are externally fired when the furnace is external to the heating surface of the boilers, as in the horizontal return tubular (HRT) boiler illustrated in figure 12.

SCOTCH MARINE (Figure 11). The Scoth Marine portable unit can be moved with ease and with a minimum of foundation work. As a complete self-contained unit, its design includes automatic controls, steel boiler, and burner equipment. These features are a big advantage because no disassembly is required when you have to take the boiler to the field for emergency work, or have to move it to a more suitable location in the area.

One advantage that the Scotch type boiler has over the water-tube boiler is that it requires less space, and can be set up in a low-ceiling room. Then, too, its tubes being all the same size saves time and trouble in making tube replacements.

The Scotch type boiler also has a few disadvantages. Its shell runs from 6 to 8 feet in diameter, a detail of construction which makes a large amount of reinforcing necessary. Too, the fixed dimensions of its internal furnace cause some difficulty in cleaning the surfaces of the section below the combustion chamber. Another drawback is encountered in the limited capacity and pressure of the Scotch type boiler.

The SETTING of the Scotch marine type of boiler is self-supporting. The shell rests in two or more cast-iron cradles, and the boiler is sometimes pitched slightly to aid in draining the boiler. The setting includes a blow-down pipe which is connected to the bottom of the shell which, in turn, is screwed into a pad riveted to the shell.

Because the Scotch marine is a fully self-contained portable boiler it is sometimes referred to as a package boiler.

HORIZONTAL RETURN TUBULAR (HRT) BOILER. In addition to operating portable boilers such as the Scotch marine type and vertical-tube boiler, the heating mechanic must also be able to operate stationary boilers, both in the plant and in the field. A STATIONARY BOILER can be defined as one having a permanent foundation and not easily moved or relocated A popular type of stationary fire-tube boiler is the HORIZONTAL RETURN TUBULAR (HRT) boiler, illustrated in figure 12.

The initial cost of the HRT boiler is relatively low, and installing it is not too difficult. The boiler setting can be readily changed to meet different fuel requirements - coal, oil, wood, or gas. Tube replacement is also a comparatively easy task since all tubes in the HRT boiler are the same in size, length, and diameter.

The gas flow in the HRT boiler is from the firebox to the rear of the boiler, then return through the tubes to the front where it is discharged to the breeching and stack.

The HRT boiler has a pitch of 1 or 2 inches to the rear. This allows sediment to settle toward the rear near the bottom blow connection. The fusible plug is located 2 inches above the top row of tubes. Boilers over 40 inches in diameter require a manhold in the upper part of the shell. Don't fail to familiarize yourself with the location of these and other essential parts of the HRT boiler. The knowledge you acquire will be a great help to you, both NOW and LATER in the performance of duties involving boilers.

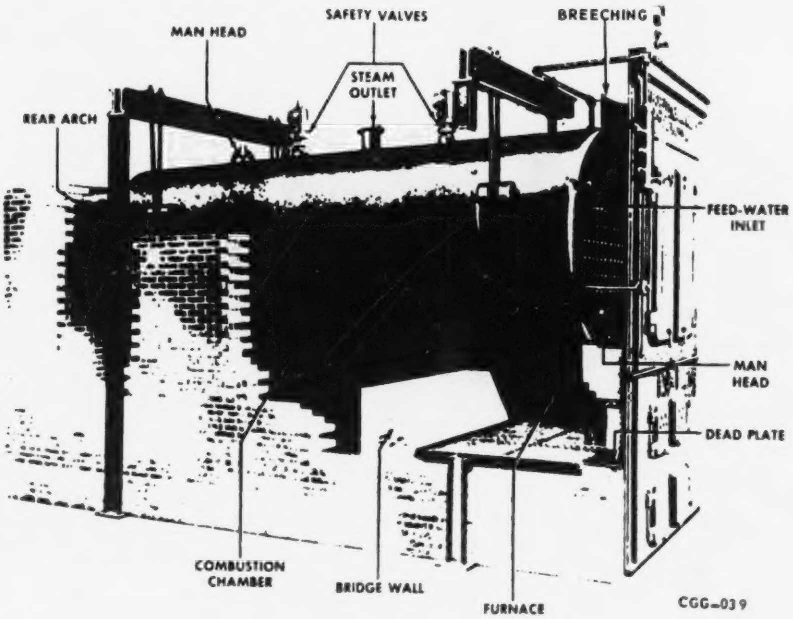


Figure 12. Cutaway of Horizontal Return Tubular HRT Boiler

FIRE BOX. Another type of fire-tube boiler is the FIRE BOX boiler, which generally is used for stationary purposes. A split section of a small firebox boiler is illustrated in figure 13. Gases in the firebox boiler make two passes through the tubes. Firebox boilers require no setting except possibly an ash pit (when using coal fuel). As a result, they can be quickly installed and placed in service. Gases travel from the fire box through a group of tubes to a reversing chamber and return through a second set of tubes to the flue connection on the front of the boiler, and are discharged up the stack.

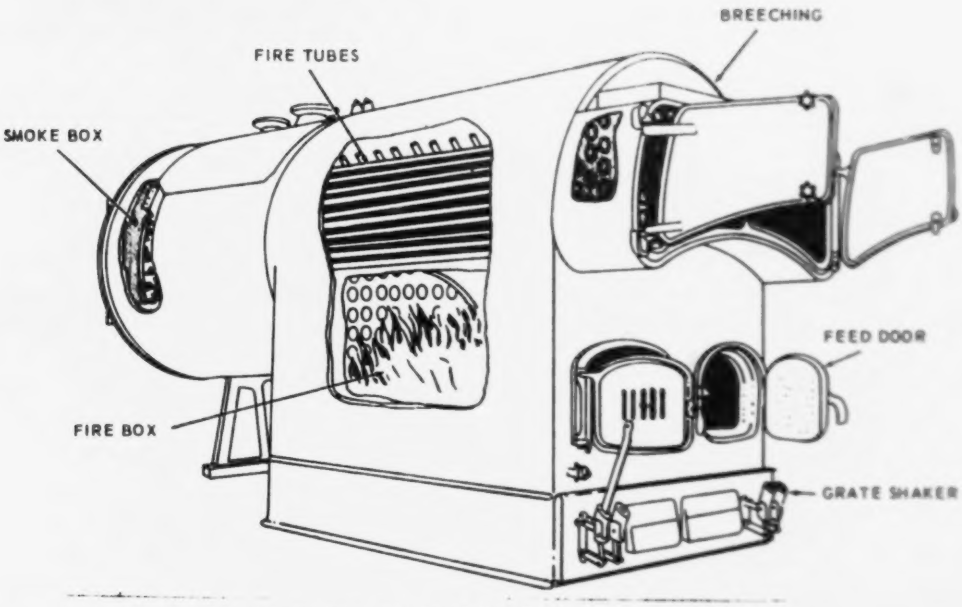

BREECHING
FIRE TUBES
SMOKE BOX
FEED DOOR
FIRE BOX
GRATE SHAKER

Figure 13. Cutaway of Double Pass Firebox Boiler

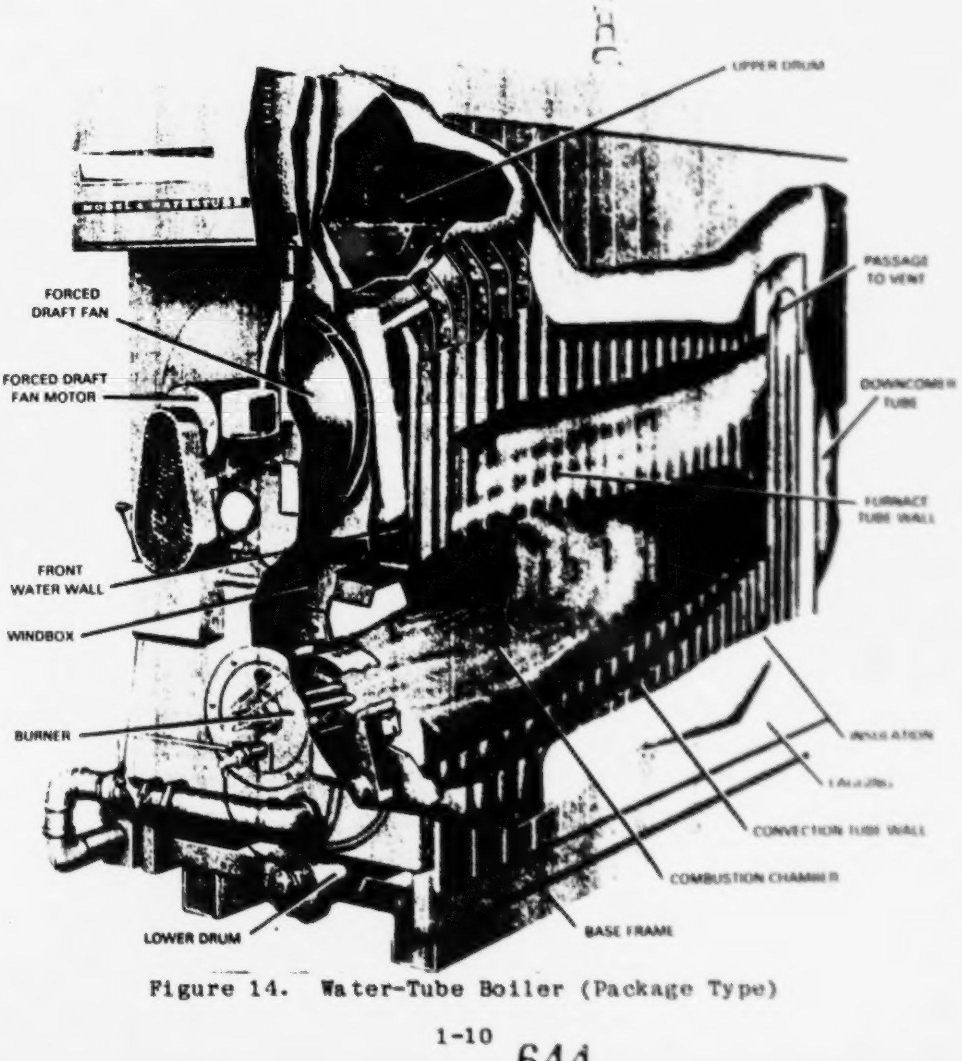

UPPER DRUM
PASSAGE TO VENT
FORCED DRAFT FAN
FORCED DRAFT FAN MOTOR
DOWNCOMER TUBE
FURNACE TUBE WALL
FRONT WATER WALL
WINDBOX
BURNER
INSULATION
CONVECTION TUBE WALL
COMBUSTION CHAMBER
BASE FRAME
LOWER DRUM

Figure 14. Water-Tube Boiler (Package Type)

Water-Tube Boilers (Figure 14)

Water-Tube boilers offer a number of advantages. They afford flexibility in starting up. They also have a high productive capacity, which ranges from 100,000 to 1,000,000 pounds of steam per hour. In case of the tube failure, there is little danger of a disastrous explosion of the water-tube boiler. The furnace not only can carry a high overload, but also can be modified easily for firing by oil or coal. Still another advantage is afforded by the minimum difficulty encountered in getting to sections inside the furnace for cleaning and repair purposes.

Now, let us look at several disadvantages common to water-tube boilers. One of the main drawbacks to the use of water-tube boilers is the high construction cost. The large assortment of tubes required for this boiler, and the excessive weight per unit weight of steam generated, are other unfavorable factors.

Water-tube boilers may be classified in a number of ways. For our purpose though, let us classify them as straight-tube and bent-tube. These two classes will be discussed separately in this section. To avoid confusion, make sure you study carefully each illustration referenced in the discussion.

STRAIGHT TUBE BOILERS. Straight tube boilers can be further subdivided into sectional-header and box-header boilers.

Sectional-Header Cross Drum. Figure 15 shows a SECTIONAL-HEADER CROSS DRUM boiler with vertical headers. Feed water enters and passes down through the downcomers (pipe) into the rear sectional headers from which the tubes are supplied. The water is heated and some of it changes into steam as it flows through the tubes to the front headers. The steam-water mixture returns to the steam drum through the circulating tubes and is discharged in front of the steam-drum baffle which helps to separate the water and steam.

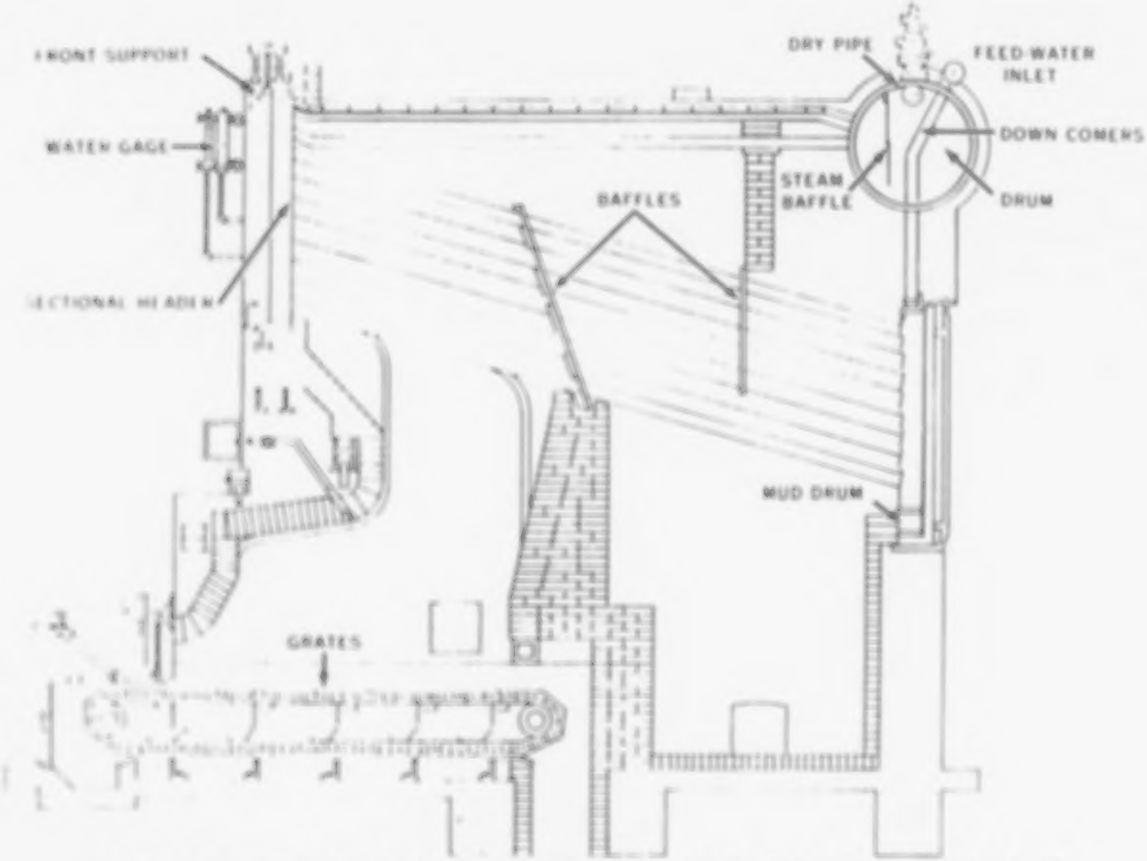


Figure 15. Sectional-Header Cross Drum Boiler (straight water tube)

Steam is removed from the top of the drum through the dry pipe.

Headers, the distinguishing feature of this boiler, are usually of forged steel and are connected to the drums with tubes. Headers may be vertical (as in figure 15) or at right angles to the tubes.

Baffles are usually so arranged that gases are directed across the tubes three times before being discharged from the boiler below the drum.

**Box-Header Cross Drum.** The BOX-HEADER CROSS DRUM BOILER is illustrated in figure 16. The boiler is usually built with the drum in front. It is supported by lugs fastened to the box-headers. This boiler has either cross or longitudinal baffling, arranged to divide the boiler into three passes.

Water enters the bottom of the drum, flows through connecting tubes to the box-header, through the tubes to the rear box-header, and back to the drum.

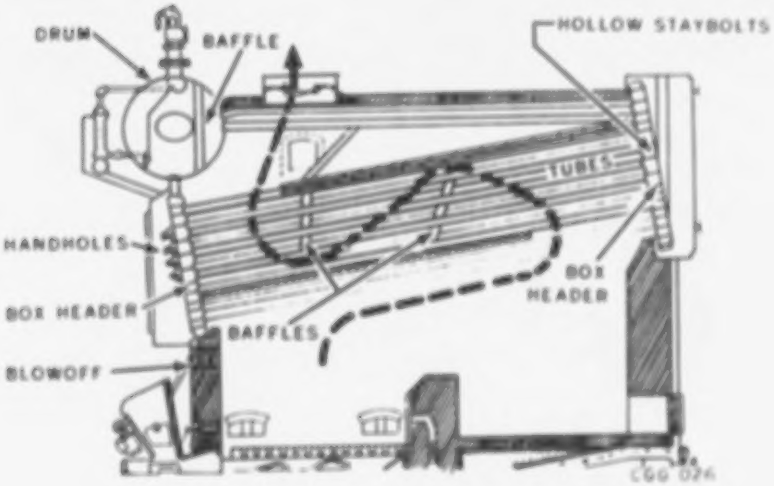
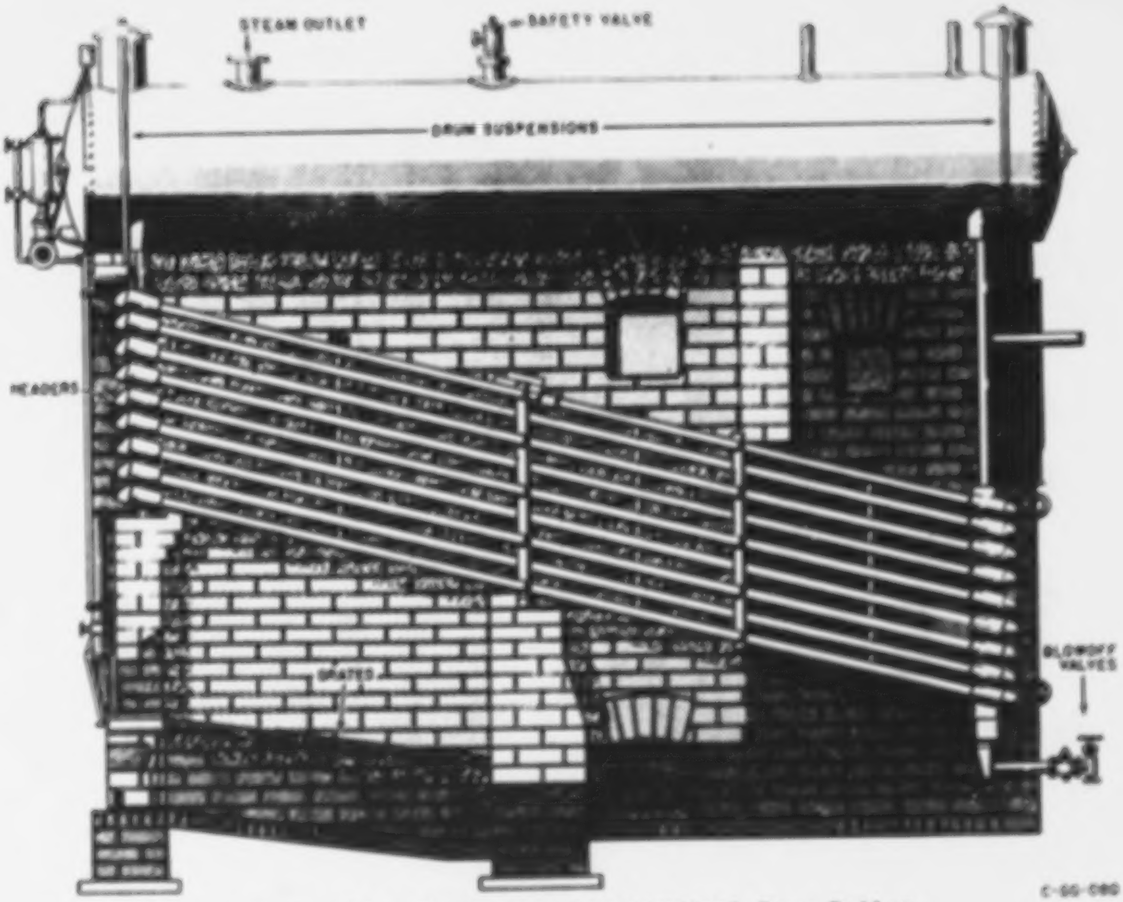


Figure 16. Box-Header Cross Drum Boiler (straight water tube).

**Box-Header Longitudinal Drum Boilers.** Box-header longitudinal drum boilers have either a horizontal or inclined drum. Box headers are fastened directly to the drum, when the drum is inclined. If the drum is horizontal, the front box-header is connected to it at an angle greater than 90 degrees. The rear box-header is connected to the drum by tubes. Longitudinal or cross baffles can be used with either type. (Figure 17.)



C-66-080

Figure 17. Box-Header Longitudinal Drum Boiler

Bent-Tube Boilers. Bent-tube (water-tube) boilers may be classified by the number and location of their drums. Figure 18 illustrates one of the types of bent-tube boilers. Boilers of this type usually have three drums, each the same in diameter but not all set on the same level. The tubes are bent at the ends to enter the drums radially.

Water enters the top rear drum, passes through the tubes to the bottom drum, and then moves up through the tubes to the top front drum. A mixture of steam and water is discharged into this drum; steam returns to the top rear drum through the upper row of tubes while water travels through tubes in the lower rows. Steam is removed near the top of the rear drum by tubes extending across the drum, and enters a small collecting header above the front drum.

Many types of baffles arrangement are used with bent-tube boilers. Usually, they are installed so that 70 to 80 percent of the heat will be absorbed by the inclined tubes between the lower and upper front drums.

PACKAGE TYPE WATER-TUBE BOILERS. Water-tube boilers, covering a range in capacity from 7,500 up to 180,000 pounds of steam per hour, have been developed as fully assembled package units. The package units incorporate a number of important features, including: compactness, simplicity, delivery and installation are facilitated. The boiler and furnaces are completely integrated with burners, automatic controls, blower, water column, pumping equipment, etc. They are suitable for small and medium sized central heating plants. Water-tube boilers of the package type have the same applications as a fire-tube package boiler.

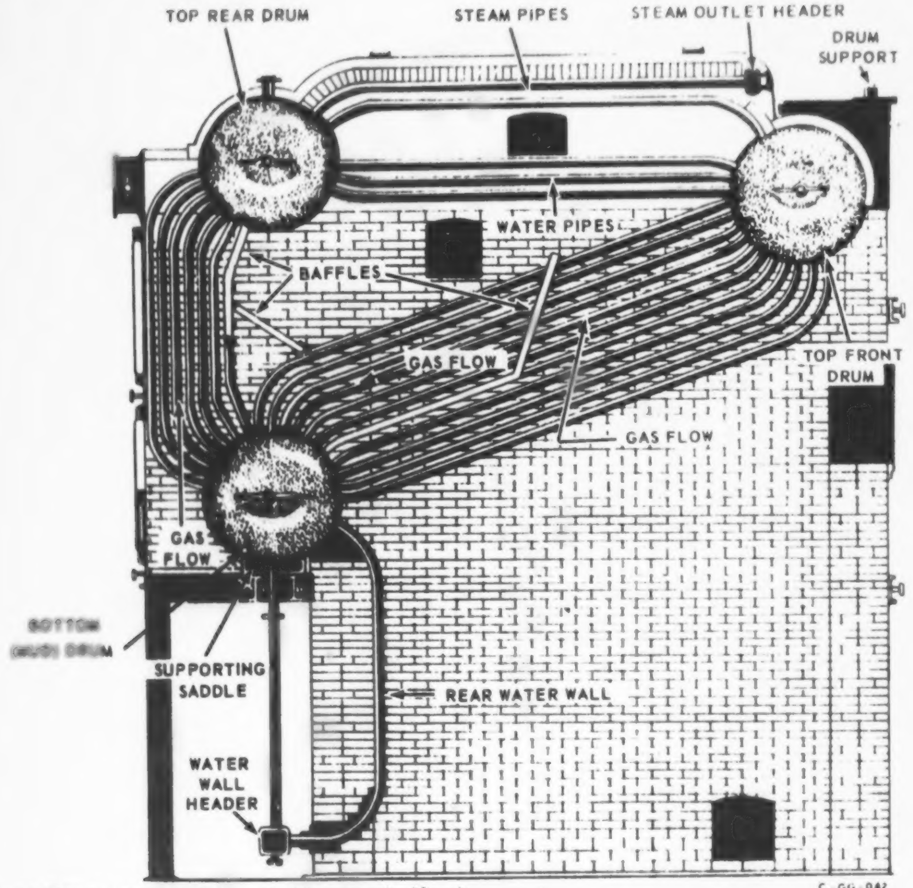

TOP REAR DRUM
STEAM PIPES
STEAM OUTLET HEADER
DRUM SUPPORT
WATER PIPES
BAFFLES
GAS FLOW
TOP FRONT DRUM
GAS FLOW
GAS FLOW
BOTTOM (MUD) DRUM
SUPPORTING SADDLE
REAR WATER WALL
WATER WALL HEADER
C-GG-042

Figure 18. Three-Drum Bent-Tube Boiler
with Longitudinal Baffle Arrangement

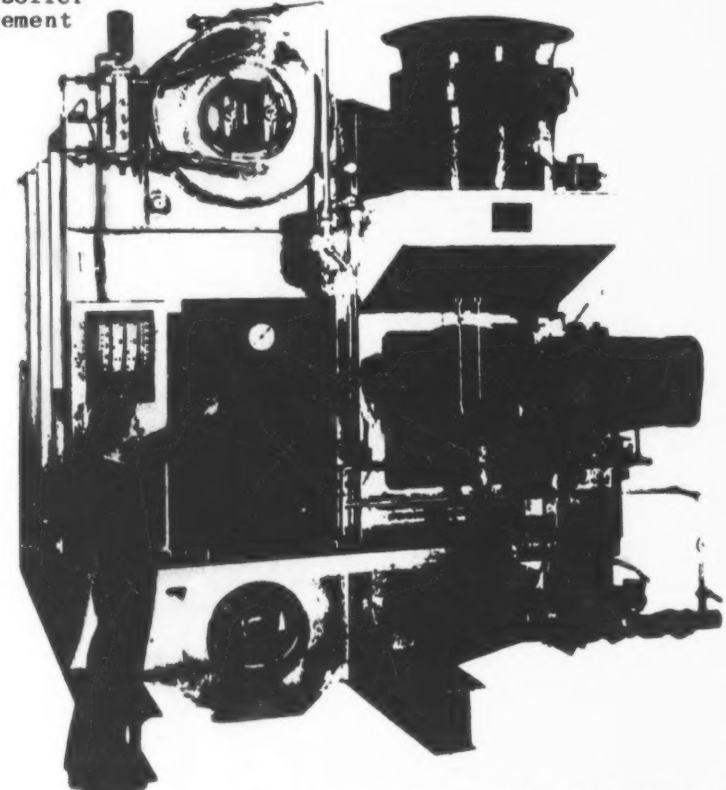


Figure 19. Water-Tube Package Boiler
Equipped for Gas and Oil Firing

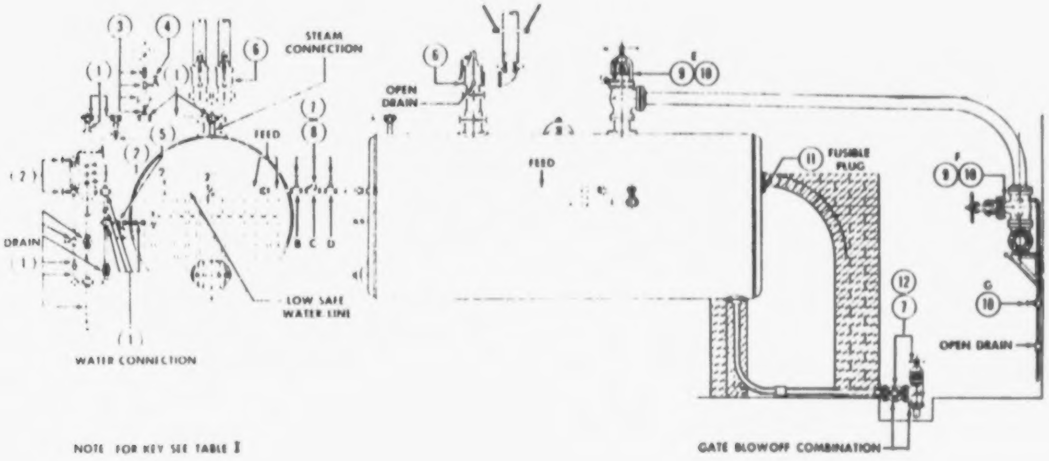
# ASME CODE

A boiler must meet certain requirements before it is considered to be a satisfactory installation. It must be safe to operate, it must generate clean steam at the desired rate and pressure, and it must be economical to operate. A set of rules for construction of stationary steam boilers, known as the American Society of Mechanical Engineers (ASME) Boiler Construction Code, has been widely adopted by insurance underwriters and governmental agencies. This code contains mandatory provisions for methods of construction and installation, materials used, design features, and recommended operating and inspection procedures.

The term "fittings" means the various controlling devices installed on the boiler. The fittings are vitally important to the economy of operation and safety of personnel and equipment. A thorough knowledge of fittings is necessary if you are to acquire skill in the installation, operation, and servicing of steam boilers.

Fittings are sometimes classified as internal and external. Internal means inside the boiler. External fittings are outside the boiler.

A number of accessories and fittings are usually installed on boilers to insure safe operation and increased economy. ASME Boiler Code requires that the following accessories be installed in a specified manner before the boiler can be operated: safety valves, water columns, pressure gauges, blowoff valves, steam-outlet valves, and feedwater valves. Table 1 and figure 20 show installation of these accessories and fittings in an HRT boiler.



NOTE FOR KEY SEE TABLE I

Figure 20. Installation of Boiler Fittings and Accessories Conforming to ASME Boiler Code

Table 1. Installation of Boiler Fittings and Accessories
Conforming to ASME Code

| KEY | RULE |
|---|---|
| 1 | Minimum size pipe between water columns and boiler is 1 inch. Use crosses at all turns. Water connection to boiler must be not less than 6 inches below center of shell. Water-column connection to ash pit fitted with drain valve must be at least 3/4-inch pipe size. |
| 2 | Each boiler must hae one water gauge with connection not less than 1/2-inch pipe size, the lowest visible part to be at least 2 inches above low safe water line. Automatic water gauges are permissible. Each boiler must have three or more gauge cocks within visible range of water glass, unless heating surface does not exceed 100 square feet, when two gauge cocks are permitted. |
| 3 | Tee or lever handle cock is the only stop permitted between gauge and boiler. For pressures exceeding 250 pounds, pipe must be steel and not smaller than 1 inch. |
| 4 | 1/4-inch globe valve for attaching test gauge. |
| 5 | When shutoff valves are used in connections to a water column they must be outside screw-and-yoke gate valves and must be locked or sealed open. |
| 6 | Each boiler must have at least one safety valve; if it has more than 500 square feet of water-heating surface, it must have two or more safety valves. Only ASME standard safety valves are permissible. Sizes 3 1/3 inches and larger must have flange inlet; sizes 3 inches and smaller can have screw connection. |
| 7 | Valves below water line; valves for feed-water and blowoff lines and for water connections to water column and drains from water column and water gauge glass. Bronze and iron valves for above services must have a steam pressure rating at least 25 percent greater than maximum allowable working pressure stamped on boiler drum. |
| 8 | Valves B and C required on all boilers. D is required only when two or more boilers are fed from one source. Inlet must be under the disk. |
| 9 | Stop valve E required on each steam line as near nozzle as practicable. Valve over 2-inch pipe size must be outside screw-and-yoke rising-stem type. |
| 10 | If two or more boilers are connected to a common pipe, valves E and F are both required. E should be nonreturn and drain G is required between the two valves. Open end of drain must be visible; no-splash funnel is ideal for this purpose. |
| 11 | Fire-actuated fusible plugs must be located at lowest permissible water level and must be renewed each year. |
| 12 | Two blowoff valves not smaller than 1-inch or larger than 2 1/2 inches required when pressure exceeds 100 pounds, except on traction or portable boilers. For pressure over 200 pounds, steel blowoff valves must be used. Globe valves must not be used as blowoff valves. |

## Safety Valve

The safety valve (figure 21) is the most important of boiler fittings. It is designed to open automatically to prevent pressure in the boiler increasing beyond the safe-operating limit. It is installed, in a vertical position, directly to the steam drum. Every boiler must have a safety valve, and there are several different types in use. Each type is designed to open completely (PO) at a specified pressure, and to remain open until a specified pressure drop has occurred. Safety valves must close tightly, without chattering, and must remain tightly closed after seating. Never operate a boiler with a known defective safety valve.

Capacity. The capacity of safety valves must be such that they can discharge all the steam generated in the boiler and still maintain steam pressure at not more than 6 percent above the maximum allowable working pressure.

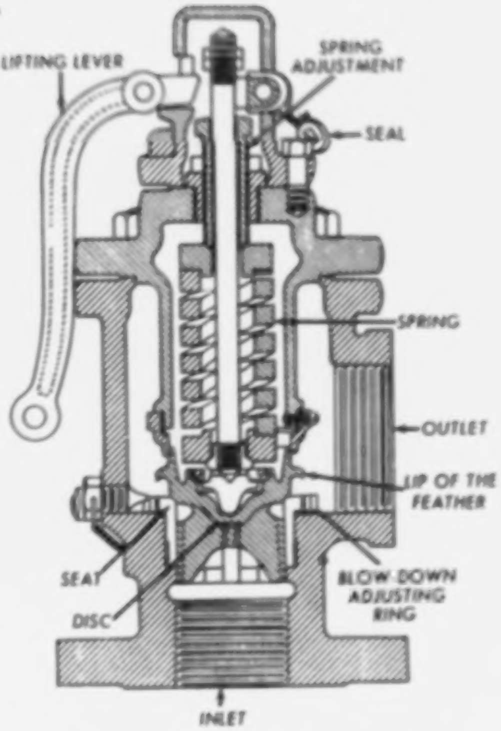


Figure 21. A Spring-Loaded Safety Valve

## Blow Off Valves

All steam heating systems must have the provision to blowdown the boiler. The object of blowing down the boiler is to remove sediments such as mud, scale, and other impurities that are harmful to the boiler. Blowdown is also used to remove excess water from the boiler.

## Blowoff Connections

Blowoff connections are normally localted at the lowest water space of the boiler. Since sediment tends to collect in the blowoff line where there is no normal water circulation, the pipe may become overheated and burn out. This line must be protected against direct furnace heat.

## Types of Blowoff Valves

SLIDING DISC OR SWING GATE TYPE. This type of valve has a swing gate or disc which moves between parallel faces so there is no wedging action and no possibility of jamming. When operated the disc rotates, preserving and regrinding the sealing joint. These valves are usually quick opening. See figure 22.

SEAT AND DISC OR HAND SEAT TYPE. These valves are usually installed with flow entering below the seat. They require at least five complete turns of the operating mechanism to change from fully open to the fully closed position and vice versa. See figure 23.

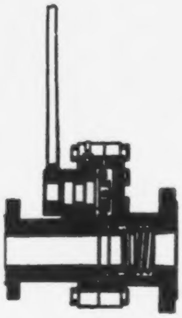


Figure 22. Quick Opening Blowoff Valve Assembly and Seats

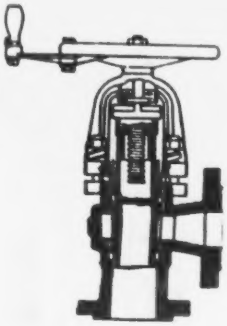


Figure 23. Typical Angle Slow Opening Blowoff Valve

### Bottom Blowoff Application and Connection

The ASME Boiler and Pressure Vessel Code, sponsored by the American Society of Mechanical Engineers, requires that all boilers carrying over 100-psi working pressure have two blowoff valves on each blowdown pipe. The arrangement may include two slow-opening valves or one slow-opening valve and a plugcock. All types of boilers must have the blowoff valves installed with extra heavy steel or malleable iron piping.

When a boiler is blown down, the quick-opening valve is opened first and the slow-opening valve is opened second. The reason for doing this is to avoid undue stress on the boiler and the blowdown piping. When sufficient blowdown time has elapsed, the slow-opening valve is closed first and the quick-opening valve is closed last.

### Surface Blowdown Valve

The surface blowdown valve will be either a manual or automatic globe valve. It is used to regulate the needed amount of surface blowdown, which was discussed earlier in this study guide.

### Continuous Blowdown

The purpose of a continuous blowdown system is to remove foreign solids and maintain the concentration of the boiler water at proper limits. (See Figure 24.)

### Flash Tank

The blowdown water or steam from the bottom blowdown and the continuous blowdown system should never be piped directly in the atmosphere or sewer because of the possibility of injuring people and damaging the sewer connections. The correct method of disposing of this hot water and steam is by the use of a flash tank, sometimes called a blowdown basin. (See figure 25.)

This tank is usually buried underground to prevent freezing. It is equipped with a bottom drain for emptying the tank when cleaning is necessary. A manhole is also provided for cleaning and inspecting purposes.

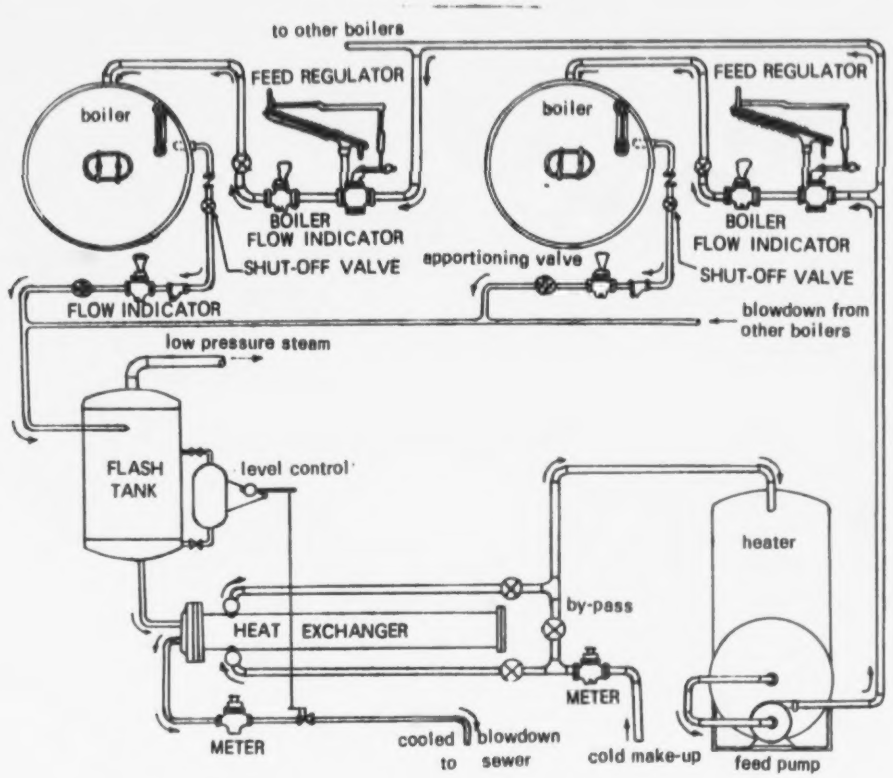

to other boilers
boiler
FEED REGULATOR
boiler
FEED REGULATOR
BOILER
FLOW INDICATOR
SHUT-OFF VALVE
apportioning valve
BOILER
FLOW INDICATOR
SHUT-OFF VALVE
FLOW INDICATOR
blowdown from other boilers
low pressure steam
FLASH TANK
level control
heater
by-pass
HEAT EXCHANGER
METER
METER
cooled to
blowdown sewer
cold make-up
feed pump

Figure 24. Continuous Blowdown System

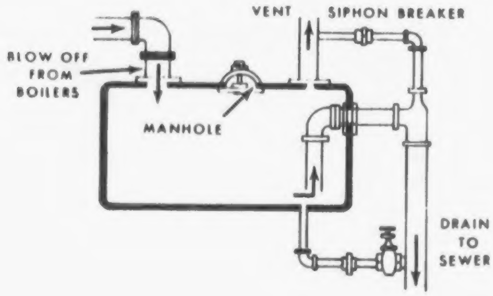

VENT
SIPHON BREAKER
BLOW OFF FROM BOILERS
MANHOLE
DRAIN TO SEWER

Figure 25. A Flash Tank Arrangement for a Bottom Blowdown

When the hot water from the boiler enters the flash tank, part of the water flashes into steam and is vented into the atmosphere. The water that does not flash into steam, however, will raise the water level in the tank and cause cold water in the tank to overflow into the sewer.

Flash tanks may also be used in continuous blowdown systems as shown in figure 25 and to prevent water hammer and other disturbances in the distribution system.

## Steam Stop Valves

The steam outlet line from a boiler must have a stop valve. If the valve is larger than a 2-inch pipe, it must be the outside screw-and-yoke, rising-stem type (see figure 26). These valves are not used for regulating purposes; they must be either totally open or completely closed. The stem position indicates whether the valve is open or closed.

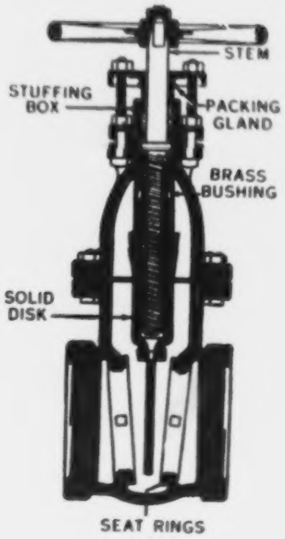

STEM
STUFFING BOX
PACKING GLAND
BRASS BUSHING
SOLID DISK
SEAT RINGS

Figure 26. Outside Screw and Yoke Type Gate Valve

## Non-Return Valves

When two or more boilers are connected to a common steam header, the ASME code and the regulations of most states call for two stop valves between the boiler and the header. Figure 27.

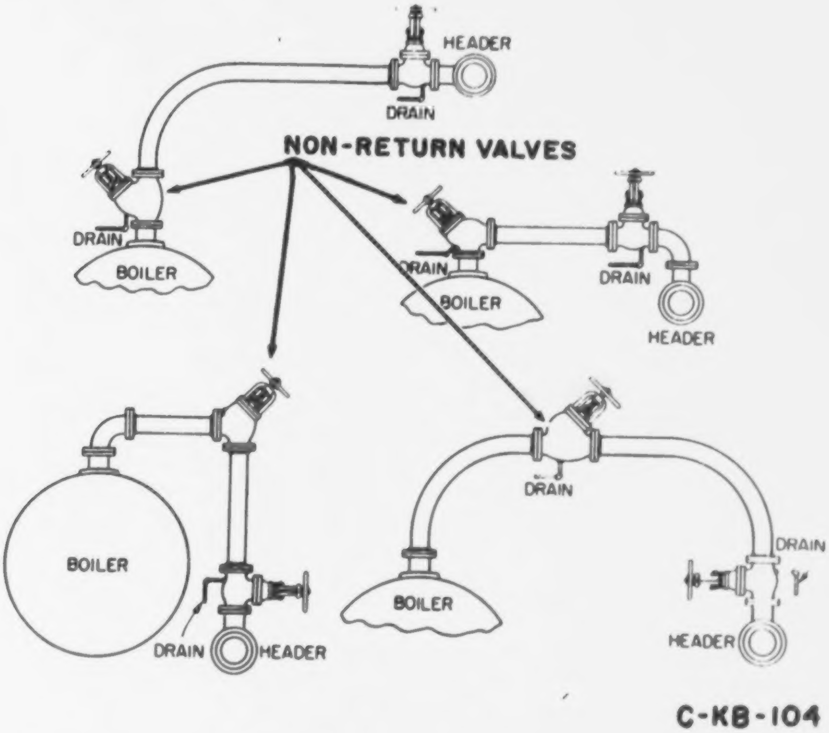

HEADER
DRAIN
NON-RETURN VALVES
DRAIN
BOILER
DRAIN
BOILER
DRAIN
HEADER
DRAIN
BOILER
DRAIN
HEADER
DRAIN
BOILER
HEADER
C-KB-104

Figure 27. Typical Installations of Nonreturn Valves

One of these valves, installed next to the boiler should be a nonreturn valve. Nonreturn valves are also called stop check valves and can be manually closed when desired. They prevent backflow from the header if a boiler fails and they simplify the work of cutting out a boiler, or bringing a cold boiler into service. The automatic operation of the valve safeguards workmen who enter a boiler to clean or repair it. See Figure 28.

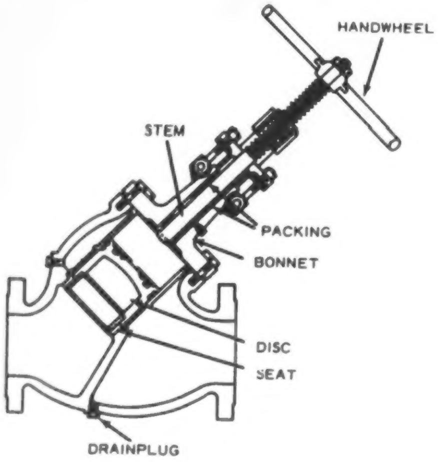

HANDWHEEL
STEM
PACKING
BONNET
DISC
SEAT
DRAINPLUG

Figure 28. Nonreturn Valves

Feedwater Valves

The feed line must have a check valve near the boiler and a stop valve between the check valve and the boiler. When two or more boilers are fed from a common source, a globe valve must be installed on the branch to each boiler, between the check valve and the source of supply. The inlet must be under the seat of the globe valve.

Water Columns

A water column is a hollow chamber made of cast iron, malleable iron, or steel according to requirements of the boiler design pressure. It has suitable connections to the boiler, water column drains, tri-cocks, and water gauge glasses. There are two connections for the boiler. The top one enters the boiler steam space through the top of the shell or head; the lower, or water connection must enter at least six inches below the lowest permissible water level. See figure 29. Water columns are used to prevent fluctuation of the water level of the gauge glass.

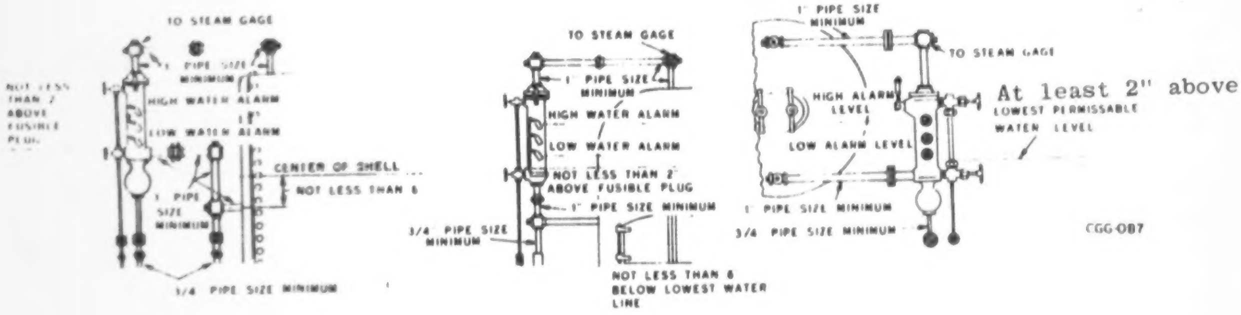
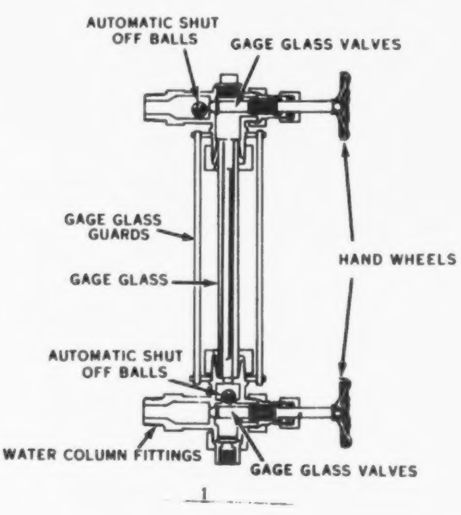

NOT LESS THAN 2 ABOVE FUSIBLE PLUG
TO STEAM GAGE
1 PIPE SIZE MINIMUM
HIGH WATER ALARM
LOW WATER ALARM
CENTER OF SHELL
NOT LESS THAN 6
1 PIPE SIZE MINIMUM
3/4 PIPE SIZE MINIMUM
TO STEAM GAGE
1" PIPE SIZE MINIMUM
HIGH WATER ALARM
LOW WATER ALARM
NOT LESS THAN 2" ABOVE FUSIBLE PLUG
1" PIPE SIZE MINIMUM
3/4 PIPE SIZE MINIMUM
NOT LESS THAN 6 BELOW LOWEST WATER LINE
1" PIPE SIZE MINIMUM
TO STEAM GAGE
HIGH ALARM LEVEL
LOW ALARM LEVEL
At least 2" above
LOWEST PERMISSABLE WATER LEVEL
1" PIPE SIZE MINIMUM
3/4 PIPE SIZE MINIMUM
CGG-087

Figure 29. Installation of Water Columns

## Gauge Glass

Water gauge glasses are used to see the boiler water operating level. They consist of a strong glass tube connected at both ends to the water column by means of special valved fittings. The ends of some glasses are annealed for longer service. Usually, the glasses are protected against mechanical damage by metal rods or special metallic screens, but this protection must never interfere with proper vision from the operating floor. Gauge glass valves can be either manually or remotely operated. See figure 30.


AUTOMATIC SHUT OFF BALLS
GAGE GLASS VALVES
GAGE GLASS GUARDS
GAGE GLASS
HAND WHEELS
AUTOMATIC SHUT OFF BALLS
WATER COLUMN FITTINGS
GAGE GLASS VALVES
1
AUTOMATIC SHUT OFF BALLS
GAGE GLASS VALVES
GAGE GLASS GUARDS
GAGE GLASS
AUTOMATIC SHUT OFF BALLS
WATER COLUMN FITTINGS
GAGE GLASS VALVES
2

1. Hand Shutoff
2. Automatic Shutoff

Figure 30. Cross Sections of Typical Gauge Glasses

If the boiler operating pressure is 400 psig or higher, two gauge glasses must be installed on the boiler.

The bottom of the gauge glasses is installed to indicate the minimum water level. See figure 29.

## Tri-Cocks

Two or three tri-cocks in the water column permit independent testing of the boiler water level. When three cocks are used, the middle cock is usually at the main water level of the boiler; the other two are equally spaced above and below it at a distance determined by the boiler size. Tri-cocks can be operated by handwheel, chain-wheel, or lever. Figure 31. ASME requires two tri-cocks must be on a water column.

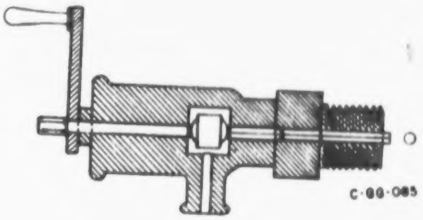


Figure 31. Handwheel Tri-Cock

### Fusible Plugs

Fusible plugs are hollow bronze plugs filled with an alloy (mostly tin) which has a low melting point (usually 450° - 500°F). They melt when the water in a fire-tube boiler is low, and so serve as a warning. One side of the plug is in contact with the fire or hot gases and the other side is covered with water. While the plug is cooled by the water, it will hold. If the water level drops below the plug, the tin melts and is blown out.

## PROCEDURES FOR INSTALLING BOILER

Except for emergency conditions, steam boiler installation is planned years in the future. Most water-tube boilers and large fire-tube boilers are installed by a contractor. Follow manufacturer's instructions if you ever need to install a boiler. No matter if the contractor or you as a heating specialist install a boiler, ASME code must be followed.

### Boiler Feedwater System

All boilers use a feedwater system to provide the water that must be added to the boiler as steam is generated. This water may be condensate that has been returned or make up water needed to replace water lost through leakage during opertation of equipment. Feedwater systems have been developed to add this water to the boiler when needed. These systems vary from a simple watermain supply used with small low-pressure boilers to the complex system used in high-pressure multiple-boiler installation.

## THEORY AND CONSTRUCTION OF STEAM AND GAS TURBINES

This section describes the main types of steam turbines, how they operate, and how they compare with gas turbines. It explains how a condenser operates, and the condenser's effect on efficiency.

### What are Turbines?

A turbine is a machine that generates mechanical power in rotary motion from the kinetic energy of a fluid (steam, air, or water). The most powerful and widely used turbines are steam turbines. Steam turbines drive many types of power plant equipment such as electric generators, pumps, and compressors. The output capacity of a steam turbine ranges from less than 1 kW to more than one million kW. The larger capacity steam turbines drive the electric generators in power plants.

A steam turbine consists of: (1) a cylinder (casing or shell) containing the fixed (stationary) blade system and a set of bearings to support the rotor shaft; (2) a rotor carrying the moving blades (buckets or vanes) with bearing journals on the ends of its shaft; (3) a governor and valve system to regulate the turbine's speed and power by controlling the steam flow, and an oil system for lubricating the bearings and for hydraulically operating the control valves by means of a relay system connected with the governor; (4) a coupling or gear reducer to connect with the machine driven; and (5) pipe connections to the steam supply from the boiler at the inlet, and to an exhaust system at the outlet, of the casing.

A steam turbine's two main parts are the cylinder and the rotor. The cylinder (stator) is a steel or cast iron housing usually divided at the horizontal centerline. Its halves are bolted together for easy access. The cylinder contains fixed blades, vanes, and nozzles that direct steam into the moving blades carried by the rotor. Each fixed blade set is mounted in diaphragms located in front of each disc on the rotor, or directly in the casing. A disc and diaphragm pair from a turbine stage. Steam turbines can have many stages.

The rotor is a rotating shaft that carries the moving blades on the outer edges of either discs or drums. The blades rotate as the rotor revolves. The rotor of a large steam turbine consists of high, intermediate, and low-pressure sections.

## Operating Principles

In a multiple-stage turbine, steam at a high pressure and high temperature enters the first row of fixed blades or nozzles through an inlet valve or valves. As the steam passes through the fixed blades or nozzles, it expands and its velocity increases. The high-velocity jet of steam strikes the first set of moving blades. The kinetic energy of the steam changes into mechanical energy causing the shaft to rotate. The steam then enters the next set of fixed blades and strikes the next row of moving blades.

As the steam flows through the turbine, its pressure and temperature decrease, while its volume increases. The decrease in pressure and temperature occurs as the steam transmits energy to the shaft and performs work. After passing through the last turbine stage, the steam exhausts into the condenser or process steam system.

The kinetic energy of the steam changes into mechanical energy through the impact (impulse) or reaction of the steam against the blades. An impulse turbine uses the impact force of the steam jet on the blades to turn the shaft. Steam expands as it passes through the nozzles, where its pressure drops and its velocity increases. As the steam flows through the moving blades, its pressure remains the same, but its velocity decreases. The steam does not expand as it flows through the moving blades.

A simple impulse turbine is not very efficient because it does not fully use the velocity of the steam. Many impulse turbines are velocity-compounded, which means they have two or more sets of moving blades in each stage. The extra sets of moving blades make use of the high-velocity steam leaving the first set of moving blades. A row of fixed blades between the moving blades directs the steam onto the next set of blades.

Another type of impulse turbine is a pressure-compounded turbine. It consists of two or more simple impulse stages contained in one casing. The casing contains diaphragms that connect to nozzles. The nozzles make efficient use of the steam pressure that remains after the steam flows through the previous stage. The pressure drops in each stage as steam expands through the nozzles.

A reaction turbine uses the "kickback" force of the steam as it leaves the moving blades to rotate the shaft. The moving blades and fixed blades have the same shape and act like nozzles. Thus, steam expands, loses pressure, and increases in velocity as it passes through both sets of blades. All reaction turbines are pressure-compounded turbines.

Many large turbines use both impulse and reaction blading. These combination turbines usually have impulse blading at the high-pressure end, and reaction blading at the low-pressure end. The blade length and size increases throughout the turbine to use the expanding steam efficiently. Blade rows require seals to prevent steam leakage where the pressure drops. Seals for impulse blading are located between the rotor and diaphragm to stop leakage past the nozzle. Seals for reaction blading are located at the tips of both the fixed and moving blades

## Types of Turbines

Because steam turbines vary widely in design, there are many different turbine classes. Steam turbines are commonly classified by blade design (impulse or reaction), steam pressure, exhaust conditions, steam path, or shaft arrangement.

Steam pressure refers to the turbine design pressure. Low-pressure turbines operate at pressures of 150 psi or lower. Medium-pressure turbines operate at pressures between 151 and 450 psi. High-pressure turbines operate at pressures greater than 450 psi. The high-pressure turbines that drive electric generators operate at pressures up to 3500 psi.

Exhaust conditions depend on whether the turbine is a condensing, noncondensing, extraction, reheat, or nonreheat unit. A condensing turbine exhausts steam into a condenser at a pressure less than atmospheric. A noncondensing turbine has an exhaust pressure the same or greater than atmospheric.

Condensing turbines are more efficient because they use more of the steam's heat energy. All large turbines that carry electrical loads for utilities are condensing turbines. Plants use noncondensing turbines to supply low-pressure steam for heating or as "topping" units. Topping units exhaust steam into another low-pressure turbine to improve plant capacity

In an extraction or bleeder turbine, part of the steam leaves the casing before reaching the exhaust end. The steam "bleeds off" through one or more extraction lines at various stages of the turbine. The extracted steam heats condensate returning to the boiler for use as feedwater.

A reheat turbine sends steam that has expanded through part of the turbine into the reheater (reheat superheater) in the boiler. The reheater raises the steam temperature to, or near, its original temperature. The reheated steam then returns to the turbine and expands to the exhaust. Reheating dries the steam so that it travels farther through the low-pressure section before condensing. A double-reheat turbine has two reheat cycles. A nonreheat turbine has no reheat cycle. Steam enters a nonreheat turbine at a given temperature, and expands through the turbine to the exhaust.

Steam flow refers to the path the steam follows through the turbine. A turbine may have single flow, double flow, or triple flow Single flow means the steam travels along a single path from the high-pressure section to the exhaust. Double flow means the steam "splits" and flows in opposite directions parallel to the shaft. Triple flow (not often used) means that a thrid part of the low-pressure steam is directed through its section parallel to the shaft. The steam flows in the same direction as the steam in one of the double flow sections. Double and triple flow paths accommodate the greater volume of low-pressure steam, and also help balance the axial (along the shaft) thrust of the turbine.

Shaft arrangement can be single, tandem-compound, or cross-compound. A single turbine consists of one unit through which steam expands and exhausts. A tandem-compound turbine consists of a high-pressure section and a low-pressure section that join end-to-end on a single shaft. The shaft drives a single generator. A cross-compound turbine consists of a high-pressure section (and intermediate-pressure section on large turbines) andlow-pressure section on separate parallel shafts. Each shaft drives its own generator.

One or more of the above classifications can apply to a given turbine. For example, a single turbine can be a tandem-compound, double-flow, reheat unit. This turbine would have its low-pressure and high-pressure sections on a single shaft, two paths for steam flow, and a reheat cycle.

Gas Turbines

A gas (combustion) turbine and steam turbine operate on a similar principle, but a gas turbine uses air instead of steam as its working fluid. A gas turbine converts the chemical energy of a fuel into mechanical energy through internal combustion. The hot combustion products expand through the turbine and perform work

Air drawn in from the atmosphere enters a rotary (centrifugal) compressor, which raises the pressure and air temperature. The pressurized, heated air leaves the compressor and enters the combustor for further heating. A portion of the air mixes and burns with the fuel in the combustor. The rest of the air mixes with the hot combustion gases to lower the air-gas mixture temperature entering the turbine.

The hot gases enter the turbine at a temperature of about 650° to 1095°C (1200° to 2000°F). As the hot gases expand through the turbine, they strike the blade, causing the shaft to rotate. The turbine drives both the load (generator, pump or fan) and the compressor. The hot gases exhaust from the turbine at about 540°C (1000°F) and atmospheric pressure.

Gas turbines have several advantages over steam turbines. Gas turbines do not require separate auxiliary equipment (boilers, condensers) as do steam turbines. A gas turbine is a single unit containing all of its auxiliary equipment. It is lighter, smaller, and takes up less space. A plant can install a gas turbine more quickly and at a lower cost than a steam turbine.

Gas turbines require less time to start up and accept a load, many power plants use gas turbines as "Peaking Units" to supply power during peak demands. Gas turbines also serve as standby units to provide power when the main turbine generators are starting up or are out of service.

### RECIPROCATING PUMPS

Reciprocating pumps are positive displacement units that impart pressure to the liquid by means of a piston or plunger with reciprocating or back-and-forth motion. All reciprocating pumps consist of two principal parts: a pump or liquid end, in which pressure is imparted to the liquid; and a drive end, through which motion is applied to the piston or plunger in the pump end. Reciprocating pumps may be single-acting or double-acting. A single-acting pump discharges only once per cycle (each double stroke); a double-acting pump discharges twice.

A horizontal duplex-piston steam pump has two steam pistons and two liquid pistons, all of which are double-acting. A duplex pump is therefore equal to two simplex pumps lying side by side. The piston rod of one pump operates the steam valve of the other through a system of bell cranks, rocker arms or links. Since the stroke of one piston begins before the other piston comes completely to rest, the water discharge is almost continuous. This pump will pump either oil or water (see figure 32).

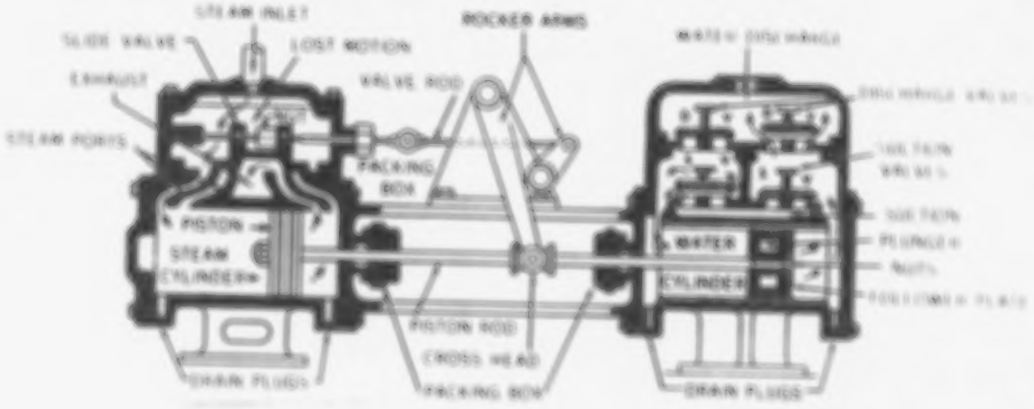

STEAM INLET
SLIDE VALVE
LOST MOTION
EXHAUST
STEAM PORTS
ROCKER ARMS
VALVE ROD
PACKING BOX
PISTON
STEAM CYLINDER
WATER DISCHARGE
DISCHARGE VALVES
SUCTION VALVES
SUCTION
PLUNGER
NUTS
WATER CYLINDER
FOLLOWER PLATE
PISTON ROD
CROSS HEAD
PACKING BOX
DRAIN PLUGS
DRAIN PLUGS

Figure 32. Cutaway View of a Duplex Steam Reciprocating Pump

### Other Parts and Classifications

STEAM END. Each end of a steam cylinder has two steam ports, as shown in figure 32. One of these ports admits steam; the other discharges it. The steam trapped in the cylinder when the exhaust stroke nears completion acts as a cushion to prevent the steam piston from striking the cylinder heads. Some pumps have small hand-operated valves on the side of the steam chest. These valves regulate the amount of cushioning by controlling the escape of the steam trapped in the cylinder. Maximum cushioning is obtained with the valves closed.

LOST MOTION. Lost motion is introduced in the valve gear to keep one piston in motion when the other is reversing at the end of its stroke. Figure 33 shows two methods of providing lost motion in a duplex pump slide valve. The valves are not fastened rigidly to the stem. This permits the piston to move during a portion of its stroke without moving the steam valve. By adjusting the lost motion, the length of the stroke can be determined.

SEALS AND DRAINS. Piston rings on the steam piston prevent leakage from one side to the other. A stuffing box, with packing and gland, seals and steam from the cylinder around the piston rod. Petcocks at the end of the steam cylinder drain condensate.

LUBRICATION. The steam end of the pump requires regular lubrication. Cylinder oil is sometimes introduced into the steam line or steam chest by means of a lubricator.

OUTPUT CONTROL. Pump output is controlled by regulating the speed of the strokes. This is done by either manual or automatic throttling of the steam supply

LIQUID END OPERATION. Several types and arrangements of valves are available for the liquid end. Each valve is designed for a particular service. Leakage around the piston is prevented by metal rings or canvas. Some pumps are equipped with a cylinder liner that can be replaced when worn. Leakage of liquid along the piston rod is prevented by a stuffing box with packing and gland.

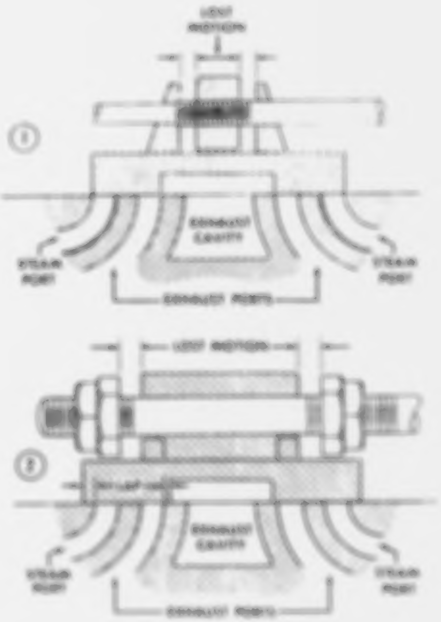


Figure 33. Two Methods of Providing Lost Motion in a Duplex Pump, Steam Valve

## Installation and Maintenance of Reciprocating Pumps

INSTALLATION. You would use the same procedures for installing a reciprocating pump as a rotary pump.

RECIPROCATING PUMP MAINTENANCE. Check as outlined under the rotary pump daily maintenance requirements covered previously. In addition, check for abnormal speed, improper stroke length, defective operation of lubricator, ineffective operation of governor, improper action of the air chamber, and steam and water leaks. To accomplish the monthly maintenance requirements, you repeat the daily inspection. Also, check for scoring of piston rods, binding of valve operating mechanism, lost motion adjustment, tilted glands in stuffing boxes, and a defective condition of strainers.

ANNUAL MAINTENANCE REQUIREMENTS. Yearly, you should dismantle the pump, clean it, and inspect for the following:

--- Liquid End. Check the condition of the valves, springs and retaining bolts; condition of cylinder liners; piston rings or packings; piston rod packing; relief valve, if used, and setting; alignment; and strainers, if used. Also, look for corrosion, erosion or excessive wear of parts, and for transmission of strains from piping to pump. Another maintenance requirement is to calibrate instruments.

--- Steam End. Check condition of pistons and piston rings, slide valves and seat; alignment; clearance between piston and cylinder liner; lubricator; and governor. Look for plugged steam passages in steam chest; scoring shoulders on cylinders; corrosion, erosion and excessive wear of parts. Calibrate instruments and replace packing. Repair or replace all defective parts found during the annual inspection.

### Safety Procedures When Operating Pumps

**TREATMENT FOR BURNS.** Severe burns are more likely to cause shock than other types of wounds, so be sure to treat for shock whenever a person has been severely burned.

Infection is another great danger in cases of severe burns. To get clothing away from the burn, cut or tear the clothes, then gently lift them off. Do not pull the clothing over the burn and do not try to remove pieces of cloth that stick to the burned areas.

If large sterile dressings are available, burned surfaces may be covered, but in the case of severe burns it is best to leave the burn exposed. Never break the blisters or touch burns.

The victim of burns should drink a lot of water because of the loss of body fluids. If possible, add salt tablets or loose salt to the water. Three or more quarts of water should be consumed by the burned victim every 24 hours. Again, medical personnel must be summoned at the earliest possible moment.

## FEEDWATER SYSTEMS

### Types of Feedwater Regulators

Boilers with 500 square feet or more of water heating surface must have at least two fully independent means of feeding, one of which shall be a pump, regulator or injector. If pumps only are used, one shall be steam driven. Each source must be capable of feeding the boiler against a pressure six percent higher than the safety valve setting.

To keep a constant water level, regardless of load fluctuations, feedwater must be injected into the boiler at the same rate that steam is generated and drawn off. The water can be injected normally through a globe valve in the feed pipe to the boiler, or automatically with a feedwater regulator. When automatic, throttling-type, feedwater regulators are installed, they must have stop valves on the inlet and outlet sides, and a throttling bypass valve for manual operation. Three commonly used feedwater regulators of the single-element system are: the float and lever or positive displacement type, the thermohydraulic or vapor generator type, and the thermostatic or thermo-expansion type.

**POSITIVE DISPLACEMENT (Float and Lever).** The float and lever regulator is of the positive displacement type, see figure 34. The float chamber is connected to the boiler steam space and water space so that its mean water level corresponds with that of the boiler. The feed valve is of the balanced type and there are no stuffing boxes to leak or cause binding.

In operation, the float follows the water level, opening the valve through a suitable system of levers to increase the waterflow. The valve and linkage provides gradual changes in the flow of water and maintains an almost constant water level. A small amount of alcohol in the float vaporizes with the heat and builds up sufficient pressure to counteract the boiler pressure on the outside of the float and prevents its collapse. To trace a feedwater system, the boiler would be the most likely place to start. Some items to look for while tracing the system are valves leaking, proper installation, and the proper operation of the float.

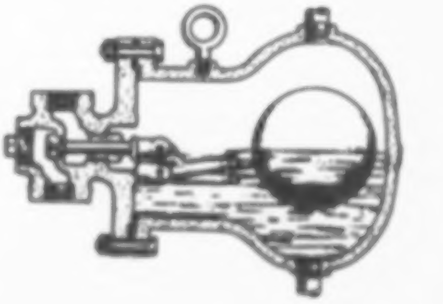


Figure 34. Positive Displacement Feedwater Regulator

THERMO-EXPANSION (Thermostatic). Now take a look at the THERMO-EXPANSION type of feedwater regulator which is sometimes called the thermostatic regulator, illustrated in figure 35. Operation of this type of regulator depends on the expansion and contraction of an inclined metal tube. The expansion tube is mounted on a steel frame. It is connected to the steam and water spaces so that the tube contains only steam when the water is at its lowest level.

The tube is then expanded to its maximum length. As the water level in the boiler rises, the water rises in the tube, and the tube contracts in relation to the rise in water level. The tube is connected to a balanced valve in the feed line by a system of levers which move the valve as the water level changes.

The length of the tube and the width of the feed-valve openings are maximum when the water level is low and the tube is filled with steam. As the water level rises, the tube shortens, closing the feed valve and decreasing the rate of flow. Note that all three of these regulators increase the flow of water as the level drops.

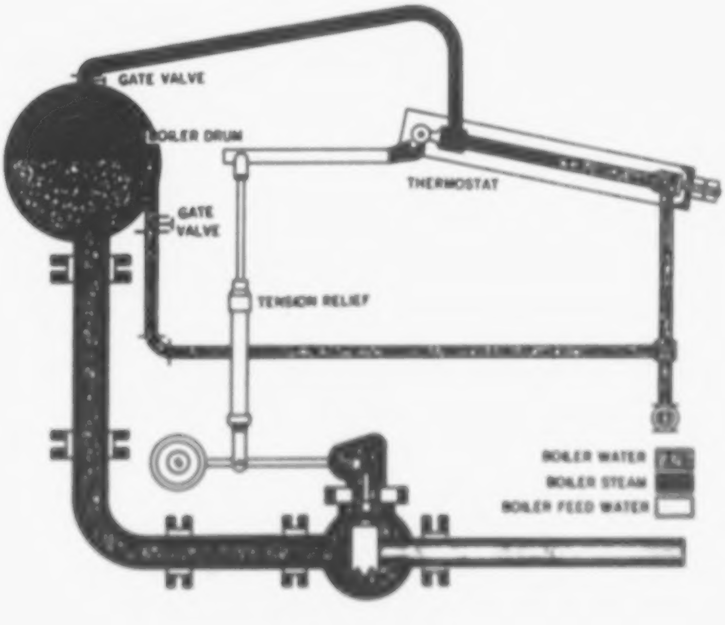


Figure 35. Thermostatic Water-Level Control

THERMOHYDRAULIC (Vapor Generator). The THERMOHYDRAULIC type of feedwater regulator (see figure 36) consists essentially of a generator and a feed-water regulating valve. The generator has an outer tube with fins for cooling. An inner tube is connected to the boiler drum, with one end entering the steam space, and the other end entering the water space. The inner tube, containing steam and water, is subjected to boiler pressure so that the water level in the generator is the same as in the boiler drum.

The outer tube connecting the metal bellows of the regulating valve with copper tubing forms a closed system. The bellows is contracted and the closed system filled with water to the level of the generator filing plug before the regulator is placed into operation. When the regulator is placed in operation, heat from the steam in the upper part of the inner tube causes the surrounding water to flash into steam.

The steam formed in the closed system expands and forces some of the water into the metal bellows, which expands and opens the valve. As the steam demand increases, more steam occupies the upper space of the closed system, thus opening the regulating valve a corresponding amount. Actually, the regulating valve operates on a pressure differential caused by the level of the water.

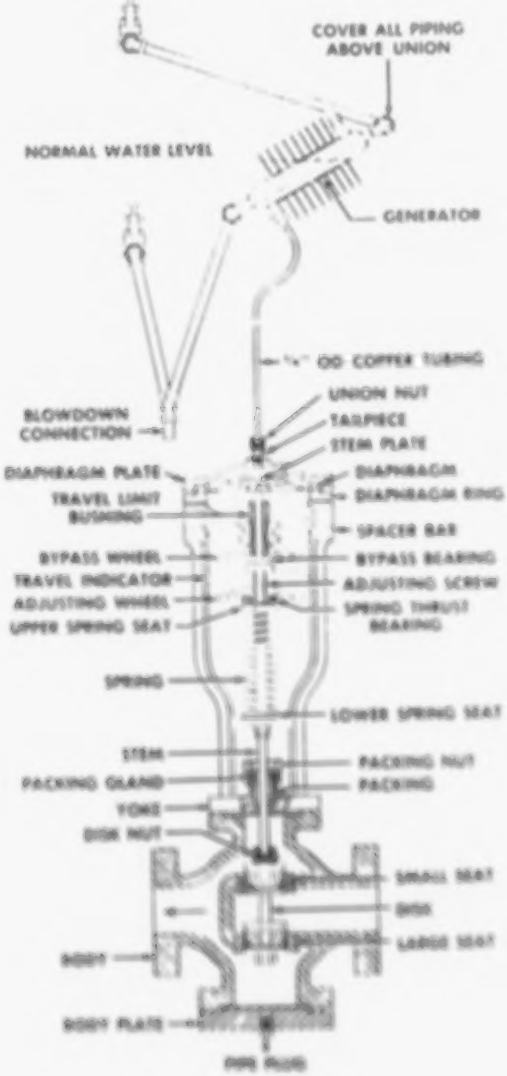

COVER ALL PIPING ABOVE UNION
NORMAL WATER LEVEL
GENERATOR
OD COPPER TUBING
UNION NUT
TAILPIECE
STEM PLATE
BLOWDOWN CONNECTION
DIAPHRAGM PLATE
DIAPHRAGM
DIAPHRAGM RING
TRAVEL LIMIT BUSHING
SPACER BAR
BYPASS WHEEL
BYPASS BEARING
TRAVEL INDICATOR
ADJUSTING SCREW
ADJUSTING WHEEL
SPRING THRUST BEARING
UPPER SPRING SEAT
SPRING
LOWER SPRING SEAT
STEM
PACKING NUT
PACKING GLAND
PACKING
YOKE
DISK NUT
SMALL SEAT
DISK
LARGE SEAT
BODY
BODY PLATE
PIPE PLUG

Figure 36. Thermohydraulic Feedwater Regulator

When the steam demand decreases, the water level tends to rise. Cold water from the storage leg plus radiation secured from the generator fins causes steam in the closed system to condense, thereby reducing the pressure until the water levels in the inner and outer tubes are again approximately equal. The decrease of volume in the closed system causes the metal bellows to contract and, at the same time, partially closes the regulating valve.

Care of Feedwater Regulators

Operators shall report immediately to their supervisors any malfunctioning of the boiler feedwater regulators. Only authorized personnel should repair, calibrate or adjust control system components. If necessary, operate on manual control or hand operate the bypass valve.

The operator should inspect each day for leaks and observe operation of all control devices. He should stop any leaks around packed stems.

Each month the operator will blow down steam and water connections, separately or as instructed by the manufacturer.

During the annual boiler overhaul, more often if necessary, clean and inspect all control components. Look for signs of corrosion, erosion, or wear and for deposits, leaks, and defective parts.

Feedwater Controls

Some boilers are equipped with a float operated feedwater control like that illustrated in figure 37. This control is attached to the water column. It functions to maintain a normal water level and protect the boiler from operating with a low water level. This control accomplishes its purpose by means of a float, arm, and a set of electrical contacts.

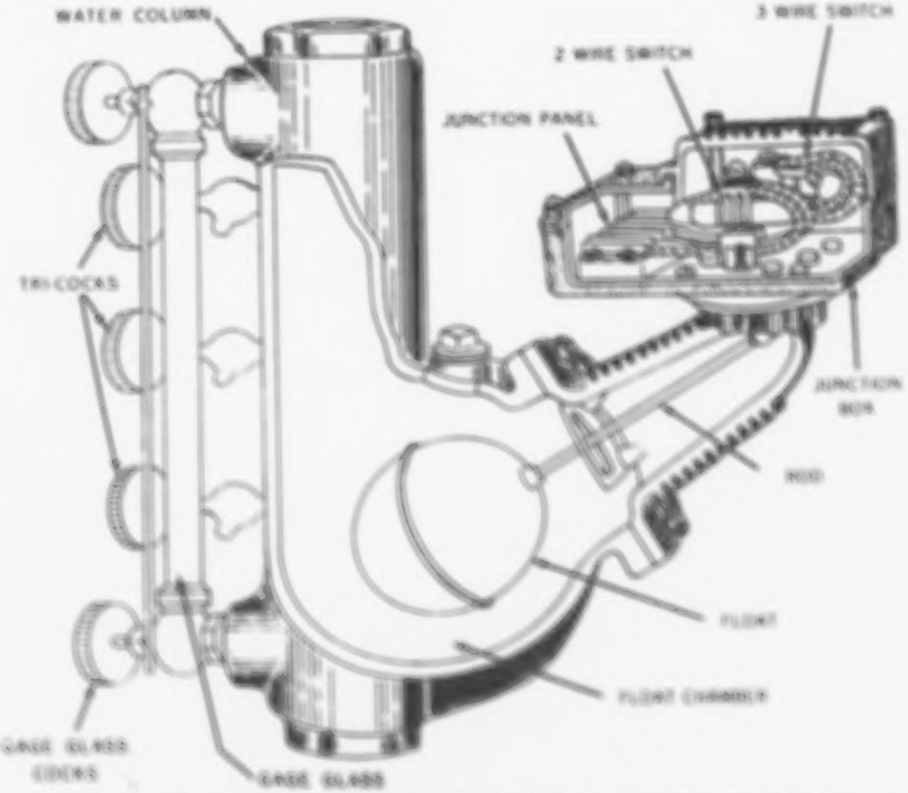


Figure 37. Cross Section of Boiler Feedwater Control Unit

The chamber is connected to the boiler by two lines which allow the water and steam to have the same level in the float chamber as in the boiler. An arm and linkage connects the float to a set of electrical contacts, which in turn operate the feedwater pump when the water level gets low. In the event the water supply fails or the pump becomes inoperative and allows the water level to continue to drop, another set of contacts operates an alarm bell and shuts off the fuel supply to the boiler.

Injector Feed System

The INJECTOR is a boiler FEED PUMP which uses speed and condensation of a jet of steam from the boiler to lift and force a jet of water into the boiler. This injection of water is many times the weight of the original jet of steam.

The injector is used to some extent in boiler plants as a stand-by feed unit. The injector will not feed very hot water. Under best conditions, it will lift 140° water about 14 feet.

The installation of an injector is not a difficult operation. The unit is mounted on the side of the boiler. Four connections (see figure 37) are made to the injector: the steam supply line from the boiler, the water supply line, the discharge line to the boiler feedwater inlet, and the water overflow line.

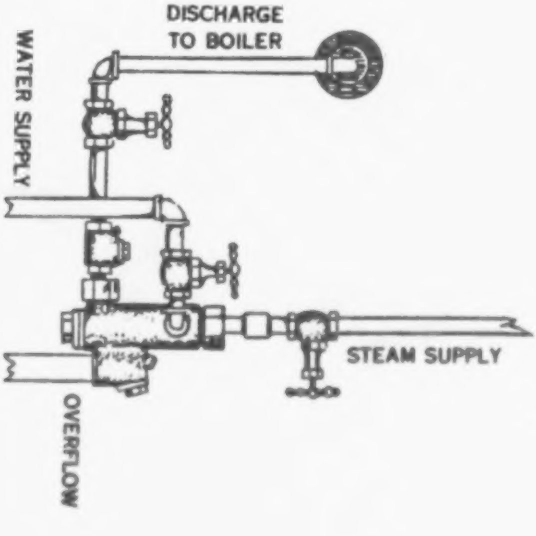


Figure 38. Injector Piping

When starting the injector, first open the water supply valve about one full turn. Next, quickly turn the steam supply valve all the way open. At this point steam rushes into the combining tube of the injector. As the steam speeds past the water supply opening it creates a suction that draws water through the opening into the combining tube. Water and steam are now mixed together inside the injector and the pressure opens a valve that leads to the boiler. Meanwhile, there is an excess of water in the injector; this excess is discharged through an overflow valve. As the next step of the procedure, slowly turn the water supply valve toward the closed position until the overflow stops. The overflow valve has now closed and all of the water being picked up from the supply line is going into the boiler. Remember that this is a feedwater system generally used as a standby system which must be operated manually. The water supply should not be hotter than 140°F for the injector to operate.

### Feedwater Tank

In normal plant operation, fluid flows cannot be kept consistently balanced. Often the demand for steam from a boiler exceeds the rate at which water is returned from the system. The reverse can also be true. Feedwater tanks compensate for such uneven flows and for the differences between the demand and supply of water at a given time. Water is stored in the tank when the supply exceeds the demand; it is withdrawn to supplement the waterfeed when the demand is higher than the supply. Feedwater tanks installed above the feedwater heater supply water to the heater by gravity flow; those installed at a low level deliver water by a pump. Tanks usually have water gauges, level controllers, overflows, drains, vents, etc., according to the type of installation.

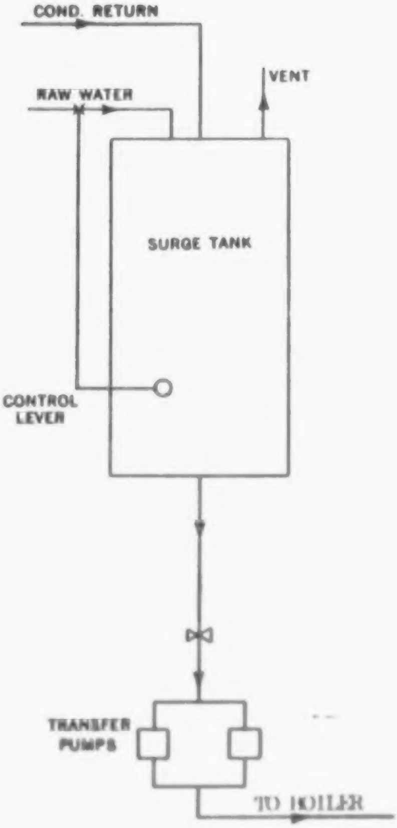


Figure 39. Typical Feedwater System with Transfer Pumps

### Feedwater System

A typical feedwater system is shown in Fig 39. This system shows the feedwater tank with connections for the condensate return line, a control lever, transfer pumps going to the boiler, also a vent on top of the feedwater tank.

### Makeup Water Systems

The makeup water system consists of a raw water line being piped to the feedwater tank as shown in Fig 39.

## BOILER CONTROL SYSTEMS

### Pressure Controls

Pressure controls are designated primarily for steam-heating systems, but are also available for controlling air, liquids, or gases that are not chemically injurious to the control.

The purpose of the pressure control is to control the pressure in the boiler by controlling the starting and stopping of the burner. The pressure control will secure the fuel-burning equipment when the pressure reaches a predetermined cut-out and start the fuel-burning equipment when the pressure drops to the cut-in point. Pressure controls may be either subtractive or additive.

The subtractive pressure control will have two settings, the cut-out and the differential. For example, if you were operating a boiler with a cut-out pressure of 100 poinds and a differential of 12 pounds, the cut-in pressure would be 88 pounds.

The additive pressure control has two settings, the cut-in point and the differential. To find the cut-out point, you add the differential to the cut-in pressure. For example, if you were operating a boiler with a cut-in pressure of 90 pounds and a differential of 13 pounds, the cut-out pressure would be 103 pounds.

The pressure control can be mounted either on a tee along with the pressure gauge or the pressure gauge tapping or it can be mounted on the low-water cut-out provided by some manufacturers. In either case, be sure that pipe dope is not permitted to enter the control. Apply the dope to the male threads, leaving the first two threads bare.

When excessive vibrations are encountered, you should mount the pressure control remotely from the boiler on a solid mounting with a suitable piping connection between them. Pressure controls must be installed at a slightly higher level than when installed on the boiler. The piping must be properly pitched to drain all condensation back into the boiler. A siphon should be connected between the pressure control and the boiler unless otherwise specified by the manufacturer

When a mercury-type switch control is used, be sure it is mounted level and that the siphon has the loop extending in the direction of the back of the control and at a 90° angle to the front. This prevents expansion and contraction of the siphon from affecting the level and accuracy of the control. The snap acting control will not be affected by this expansion and contraction

Only certified personnel will make changes in the setting of a pressure control because of its vital importance in the operation of a boiler. Figure 41 shows a typical pressure control.

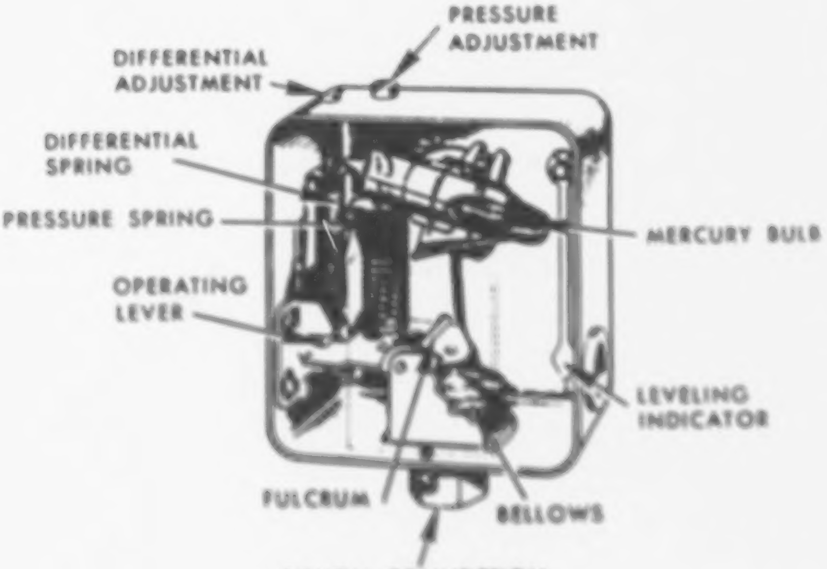


Figure 40. A Diagram for a Pressure Control

Steam systems require a pressure limit control to interrupt the burner in the event of unsafe boiler pressure. This control should be in addition to the operating pressure control and should be set at a slightly higher pressure so that it does not function in normal boiler operation.

### Burner Interlock Control

Interlocks may be required in addition to the operating and limit controls for safe operation of commercial and industrial burners. Burner interlock controls perform two functions;

1. Prove that the burner is ready to be started.
2. Prove that conditions are satisfactory for the burner operation to continue.

Use of interlocks depends on size, type of burner, and codes. The complete control system for the commercial-industrial burners could include the following controls: (1) low water cut-off, (2) low-fire start, (3) highsteam pressure, (4) high water or air temperature, (5) low oil temperature, (6) low oil pressure, (7) high oil temperature, (8) combustion air-flow switch, (9) air-flow switch to prove purge, (10) high gas pressure, (11) low gas pressure, (12) cock or valve switch, (13) uptake damper, and (14) draft controls. There are many others for specific conditions.

### Airflow Switch

Steam boilers usually have an air-flow switch to insure shutdown of boiler and proper purge in the event of fan failure.

### Firing Rate Control

Most large commercial-industrial burners have a means of adjusting the firing rate within the maximum (cut-out) and low-fire (cut-in) range of the burner. This change in firing rate may be governed by either electric, hydraulic, or pneumatic controls. Burners with firing rate controls are required to be started at a low firing rate. The firing rate controls may allow the burner to go to a high fire rate, immediately after ignition when the main fuel valve opens, or may hold at the low firing rate until the burner stabilizes and the draft becomes established before permitting the burner to go to the high fire position regardless of the type of firing rate, the controls employed, or the means used to accomplish it, the assured low fire start provides a smoother ignition.

## TYPES OF GAUGES

### Draft Gauges

The draft gauge is used to measure very low pressures. In boiler practice, a pressure difference which produces a gasflow is called a draft. Draft gauges can be made as indicators, recorders, or both.

U-TUBE. The simplest type of draft gauge consists of a U-tube partly filled with water. One leg of the tube is connected to the source of draft and the other is left open to the atmosphere. The difference in level between the liquid in the two legs gives the draft in inches of water. In some models, one leg of the U tube is arranged on an incline to increase the distance covered by the liquid in the inclined portion for a given draft change. The slope normally used is one inch in ten. Other types of draft gauges use diaphragms or bellows as the measuring element.

DIAPHRAGM TYPE. Figure 4 illustrates a diaphragm-actuated, draft gauge. In operation, one side of the diaphragm is connected to the source of draft and the other is open to the atmosphere. The motion of the diaphragm is transmitted to the indicating pointer through proper linkage. This type of gauge may be used also to measure small pressures above atmospheric such as windbox pressures. The unit of measure is in inches of water. The connections are over the fire, last pass, and breeching or stack. The requirements for proper draft are .03 to .06 inches of water.

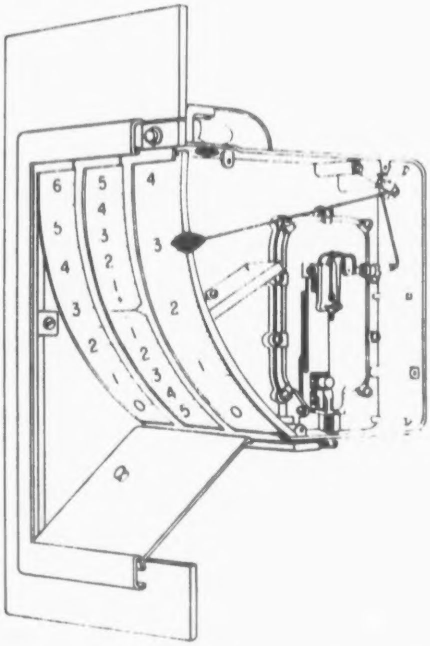


Figure 44. Diaphragm Type Draft Gauge

Pressure Gauges

Every boiler must be equipped with a steam pressure gauge connected to the steam space of the boiler. The Bourdon is the main type of pressure gauge (figure 42). Its measuring element is a tube of flattened cross section bent into an arc. One end of the tube is closed; the other is connected to the pressure source. When the pressure in the tube increases, it tends to become circular in cross section and, as a result, the tube is straightened. The reverse occurs when the pressure is reduced. The free end of the tube is connected through a gear sector and pinion to a pointer moving on a calibrated dial. Bourdon tubes are made of different materials to conform with design pressure. The gauge dial is usually graduated to read approximately twice the pressure at which the safety valve is set; however, it is never graduated to read less than 1 1/2 times this pressure.

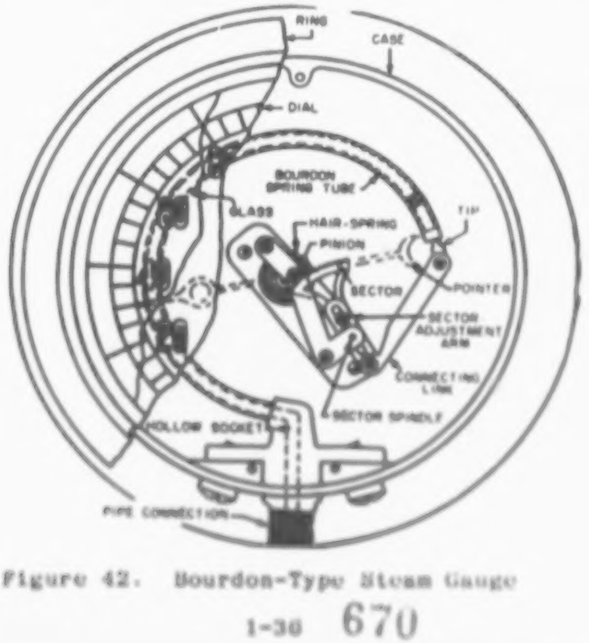

RING
CASE
DIAL
BOURDON SPRING TUBE
GLASS
HAIR-SPRING
PINION
TIP
SECTOR
POINTER
SECTOR ADJUSTMENT ARM
CONNECTING LINK
SECTOR SPINDLE
HOLLOW SOCKET
PIPE CONNECTION

Figure 42. Bourdon-Type Steam Gauge

### Recording-Type Pressure Gauge

Pressure recorders generally use a tube of oval cross section wound in a helical coil. The free end of the coil is connected to the pen arm (directly or through linkage and levers); the other end is connected to the pressure source. The operating principle is the same as for the Bourdon tube. The chart upon which the pen records is driven by clockwork or a synchronous electric motor.

### Methods of Calibrating Gauges

Pressure gauges should be checked annually and calibrated or replaced as required. Two methods of calibration may be used: air pressure and deadweight tester.

AIR PRESSURE. Adequately pressurized air is a convenient pressure source when checking gauges. An air filter should be installed ahead of the connection to the gauges to provide them with clean air during the test.

DEADWEIGHT TESTER. A deadweight tester is often used to periodically check, test, and service gauges. The deadweight tester is a hydraulic unit, precision-built to obtain basic pressure standards. It consists of a manually operated oil pump assembly in which a weight platform is made from the oil pump to the gauges being tested.

A laboratory test gauge should be used as a reference for checking the accuracy of the deadweight tester. Laboratory test gauges are accurate to within 1/4 of one percent. Laboratory test gauges should never be used as service gauges.

In operation, calibrated deadweights are placed on the weight platform and the pump is manually operated until the platform is freely supported by the piston.

The oil pressure (which is shown on the gauge dial) must correspond with the pressure stamped on the calibrated deadweight. The gauge pointed must be reset to indicate the correct pressure shown by the testing method used. Some gauges are calibrated by adjusting screws in the level system mechanism or by removing the pointer and replacing it to the proper pressure. Refer to the manufacturer's instructions for the correct method of pointer resetting and hair spring adjustment.

### Recording-Type Pressure Gauges

Refer to the manufacturer's instructions for the correct method of testing.

### Steam-Flow, Airflow Meter

Figure 43 illustrates one type of steam-flow, air flow meter. The steam flow section consists of a bell floating in mercury (secondary element). The localized pressure drop created by the primary element in the steam pipe is transmitted to the bell through the low- and high-pressure connections shown. In operation, as flow through the primary element varies, the mercury level changes and the bell rises or falls accordingly. The motion of the bell is transmitted to a small shaft and through a pressure-tight bearing to the linkage which operates a pen that records the flow rate on a chart. Because of the special shape of the bell (called Ledoux bell) its movement is directly proportional to the change in flow. Figure 44 shows the airflow section of the steam-flow air flow meter.

### Air Measurement Meter

The function of this meter is based on the fact that the amount of air supplied to a furnace is related to the amount of flue gas that passes through the setting. The gas-flow, therefore, indicates the air actually supplied to the furnace. Resistance to the flow of the combustion gases through the setting causes a pressure drop (draft loss) similar in effect to the localized drop created by a primary element in the steam pipe. The secondary element consists of two airflow bells, supported from knife edges on a beam which pivots on other knife edges, and a mercury-displacer assembly hanging from a knife edge on the beam. The bottoms of the bells are connected to the two points (S and F) of the boiler setting. In operation, changes in gasflow produce movements in the beam which are transmitted through linkage to the pen that records the airflow.

The parabolic shape of the mercury makes the movements of the beam directly proportional to the changes in gasflow. This meter can be calibrated so that steam-flow and airfl[illegible] pen recordings run together when the desired amount of air is supplied. Then, if too much air is supplied, the air flow pen moves higher on the chart than the steam-flow pen; if too little, it moves lower.

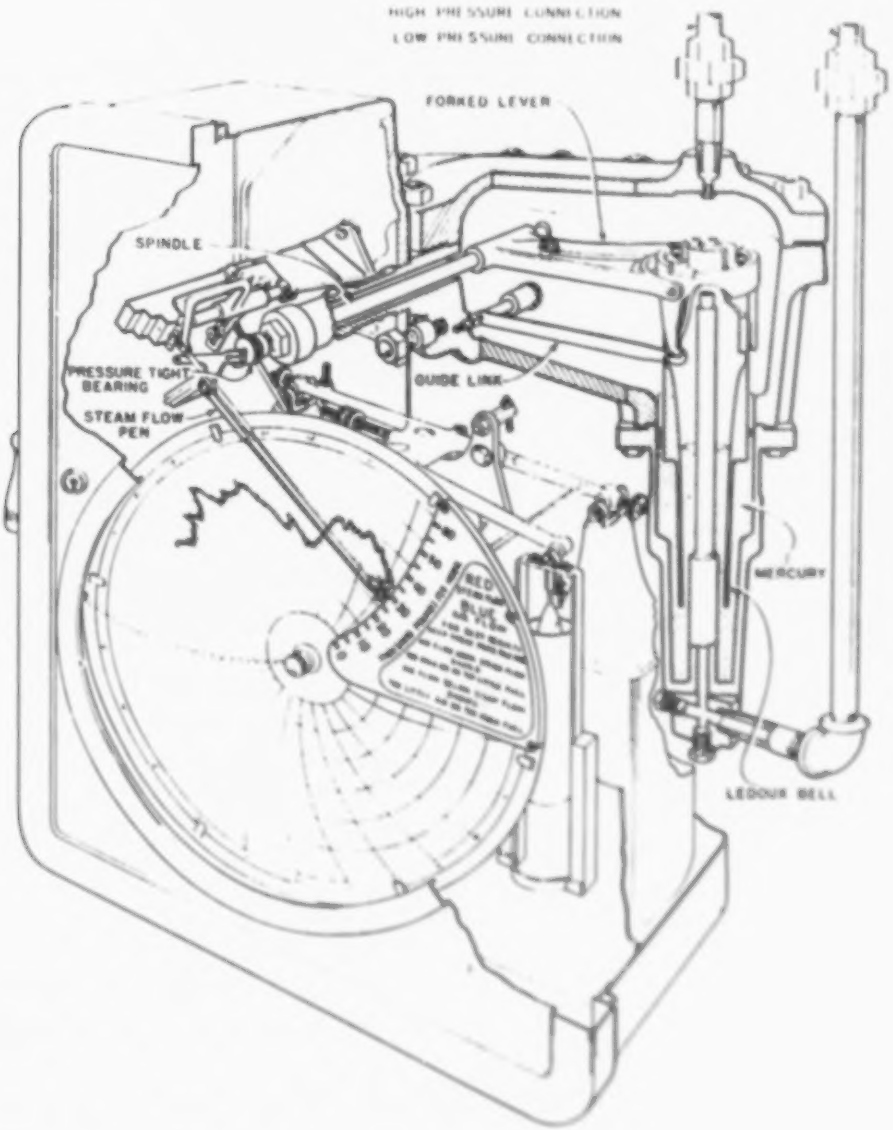

HIGH PRESSURE CONNECTION
LOW PRESSURE CONNECTION
FORKED LEVER
SPINDLE
PRESSURE TIGHT BEARING
STEAM FLOW PEN
GUIDE LINK
MERCURY
LEDOUX BELL
RED
BLUE

Figure 43 Steam-Flow Airflow Meter

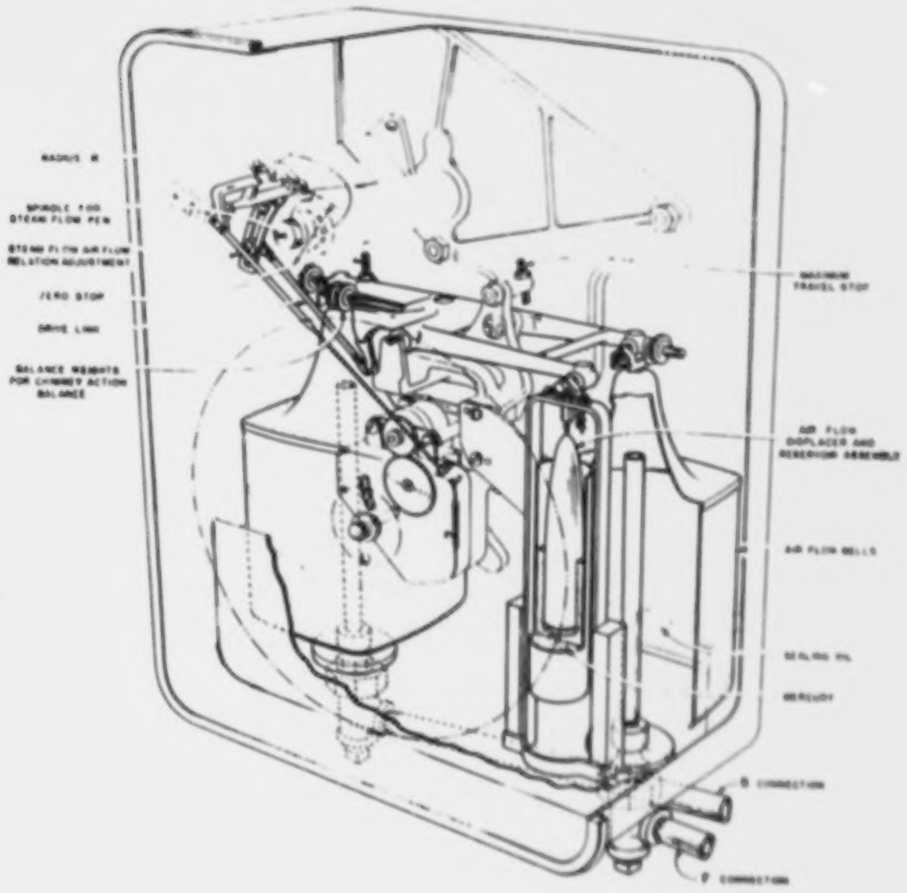

RADIUS R
SPINDLE FOR STEAM FLOW PEN
STEAM FLOW AIR FLOW RELATION ADJUSTMENT
ZERO STOP
DRIVE LINK
BALANCE WEIGHTS FOR CHIMNEY ACTION BALANCE
MAXIMUM TRAVEL STOP
AIR FLOW DISPLACER AND RESERVOIR ASSEMBLY
AIR FLOW BELLS
SEALING OIL
MERCURY
B CONNECTION
F CONNECTION

Figure 44. Airflow Section of Steam-Flow Airflow Meter

Flow Meters

Flow meters are instruments used to measure the rate of fluid flow. Often, they are indicating-recording types, with integrators which total the amount of flow in a given period of time. The primary element in commonly used flow meters is an orifice, flow nozzle or venturi tube installed in a pipe or duct (see figure 45). The operating principle is the same in all three types. The primary element produces a localized pressure drop in the line which depends on the rate of flow. One commerical flow meter has an orifice, flow nozzle or venturi tube and a secondary element to measure and translate the pressure drop into pounds per hour, cubic feet per second (cfs), gallons per minute (gpm), or any other unit desired.

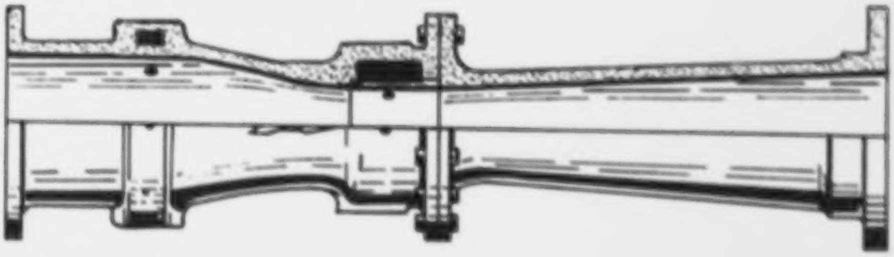


Figure 45. Venturi Tube for Flow Metering

## Temperature Meters

These instruments are used to measure the temperature of a fluid. They can be indicating (generally called thermometers) or recording types. The most common thermometer consists of a glass tube from which air has been removed. The upper end is closed; the lower is expanded into a bulb and filled with a suitable liquid, such as mercury. When the bulb is heated, the liquid expands and rises in the tube; it contracts and drops when the bulb is cooled. Dispersement of the liquid through the tube is proportional to the intensity of the heat. Divisions marked on the tube, or on an adjacent surface, indicate the degree of temperature. Thermometers for remote indication may consist of a gas-filled system which includes a bulb, capillary tubing, and helical coil. Temperature changes at the bulb end actuate the coil at the other end. Length of capillary varies with bulb size. This type of thermometer can be adapted for recording by attaching a pen through proper linkage at the free end of the helical coil. The pen records on a chart, mounted on a rotating assembly which is operated by clockwork or a synchronous electric motor.

## Servicing of Pressure/Temperature Recording Equipment

Daily. Replace charts at the same time each day (usually at 12:00 midnight). Inspect for leaks and correct operation. Yearly. Inspect for the following: (a) leaks in piping or equipment, (b) corroded, eroded, worn out, or otherwise defective parts, (c) plugged internal passages, (d) clogged pipes, tubing, or connections, (e) loose connections, (f) defective gaskets, diaphragms, or bellows, (g) dirt or foreign material, (h) short circuits, open circuits, defective transformers, loose connection, grounds, or defective insulation in electrical type meters, (i) defective operation of clockwork mechanism or electric motor, (j) binding of moving parts, (k) incorrect meter calibration, (l) mercury contamination.

## Servicing Draft Indicating and Regulating Equipment.

The servicing of draft indicating and regulating equipment is essentially the same as servicing of pressure/temperature recording equipment as well as servicing of flow meters and records.

## PROGRAMMING CONTROL

The programming control system provides ignition and flame failure protection for industrial and commercial oil, gas, or combination oil/gas burners. In conjunction with operating, limit and interlock devices, it automatically programs each starting, operating and shutdown period. The system consists of a programming control and a scanner that uses the cell to visually supervise both oil and gas flames.

The system monitors both main and pilot flames and does not permit the main fuel valve to be energized unless pilot flame has been established and proved. With an alternate connection for burners having direct spark ignition, the unsupervised trial-for-ignition period is precisely restricted to a safe short interval.

A programmer control programs the operation of blower and/or burner motor, ignition system, fuel valve, and modulator system in a proper sequence that includes suitable purge periods before ignition and after burner shutdown. Additionally, it is designed to close all fuel valves within 1 to 4 seconds upon loss of flame signal. The control recycles automatically each time the operating or limit control closes, or after a power failure, but locks out and must be reset manually following flame failure.

A scanner system on some programmers incorporates a safety-checking circuit that is effective on every start. Any condition that will cause the flame relay to hold in during the checking period will stop the program before any ignition circuits are energized and, if sustained, will result in safety lockout.

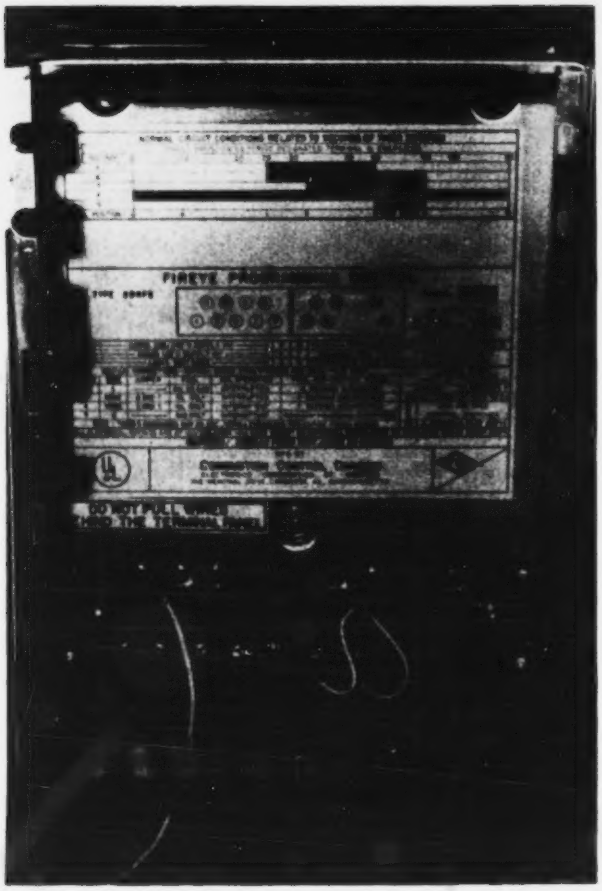


Figure 46. Mounting Base Programmer

All wiring connections are made to the terminal panel at the bottom of the housing. (See figure 46.) Separate knockouts are provided for conduit connections for line voltage and scanner circuits. Generally, models may be interchanged without changing any wiring connections. On some models you must verify all wiring connections before operating. The control chassis plugs securely into the housing and is secured by the two thumb screws. (See figure 47.) The scanner may be located up to 100 feet from the control. Continuous conduit bonding between scanner and control is mandatory. Do not pass scanner wiring through any junction box containing other wires, and do not run other wires through scanner conduit. The reason for this is that stray voltage from other wires can affect the scanner signal.

Maintenance of some scanner systems has relay contacts designed with adequate wiping action for self cleaning under normal conditions. In atmospheres carrying excessive dust or oily vapors, contacts may require occasional cleaning. Use only a fine grade of crocus cloth for cleaning. Do not file. To protect against high-resistance leakage in an electronic circuit resulting from high humidity, it is recommended that the control be left powered continually even when not in operation. If it is necessary to shut down completely for an extended period, power should be turned on for 48 hours before putting the control back in operation. It is recommended that units purchased as spares be rotated periodically, so that each unit will be placed in operation at least every 90 days, to ascertain that the spare unit is in working order. This will prevent possible deterioration of a unit stored over a period of years.

In addition to the above mentioned maintenance, the following should also be included:

a. Perform a flame-failure check and pilot turndown test whenever the burner is serviced at least annually.

b. Inspect and clean the detector and any viewing windows as often as soot accumulation and heat conditions at the detector make it necessary.

c. Perform a flame current check at least monthly, and more often where a shutdown may be costly.

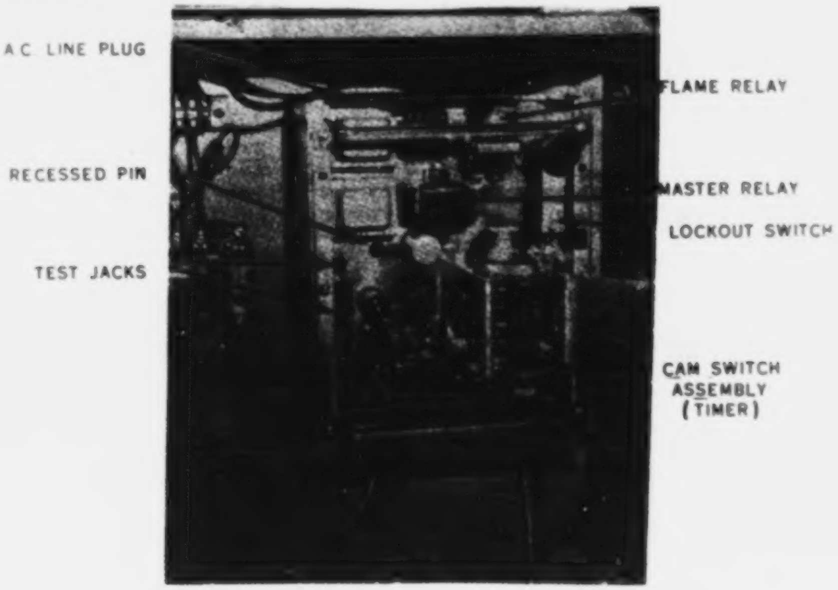


Figure 47 Programming Control

SUMMARY

We have studied the purpose of a Central heating plant, the components that keep the central heating plant operating, the control systems on the high pressure boiler and types of water tube and fire tube boilers. It is important to remember that each manufacturer will have their own type of control system.

1. Using a subtractive type pressure control, you want the burner to shut off at 20 psig steam pressure, but in at 15 psig, what would the settings be on the control?

2. What is a central heating plant?

3. What boilers are considered portable?

4. Name the pressure parts of a boiler.

5. What is the difference between fire tube and water tube boiler?

6. According to ASME code, name the sequence of blowing off a boiler.

7. What is the minimum pipe size between water column and boiler according to ASME?

8. What is a turbine?

9. What are the basic parts of a turbine?

10. Name the types of feedwater regulation.

11. What part of the thermo expansion type feedwater regulator depends on the flow of water into the boiler?

12. What operates the valve on a thermohydraulic feedwater regulator?

13. Briefly explain how a reciprocating pump operates.

14. How many tricocks must be installed on a water column?

15. What are interlocks?

16. How often are programmers rotated on a basic control system?

17. Explain how air flow meter works.

18. What are the types of draft gauges?

19. What is the main type of pressure gauge used?

20. Where is the pressure control mounted?

3770 Technical Training Group
Civil Engineering Training
Sheppard Air Force Base, Texas

SG J3ABR54532 001-VI-2

# BOILER OPERATIONS

## OBJECTIVES

Given information, operate a steam boiler with instructor assistance.

Given information, determine step-by-step procedures for oeprating and maintaining oil preheaters with 70% accuracy.

Given simulated job type entries, complete steam logs and fuel consumption report with instructor assistance.

## INTRODUCTION

The following will be covered in this unit:

Boiler Operation

Emergency Shutdown Procedures

Plant Operating Logs

## INFORMATION

## BOILER OPERATION

### Preoperational Inspection

Before starting up a boiler, inspect the installation carefully and make certain the following requirements are satisfied.

--- All installation, repair, and cleanup work completed.

--- All air and flue gas ducts and passages are tight and free from obstructions, and air and flue gas control dampers in good operating condition.

--- Check all piping for leaks.

--- Inspect water column blowdown lines and gauge glasses for proper installation and connection. Gauge glasses should be clearly visible from the operating floors and lamps, if provided, ready for operation. The drain valve on the water column must be closed and the valves between the column and boiler locked open.

--- All valves must be inspected: Good operating condition, bent stems, and missing or broken hand wheels.

--- Check all auxiliary equipment such as fuel burning, draft, ash disposal, feedwater and combustion control systems for proper installation and operational readiness. Make certain safety valve gauges have been removed, and valves properly set and workable.

--- Make sure all boiler manhole and handhole covers have been reinstalled. Check to make certain no one is inside, then see that all access and observation doors are closed.

--- Electrical system should be checked for: oil-soaked or frayed wire insulation, damaged or loose conduit, and improperly secured control boxes.

--- Make sure guards for moving parts are tight and in proper position.

--- Pressure guages must be correct and clean. They must be well lighted and the cock in line must be open.

--- Auxiliary equipment: Be sure to inspect and check out, as far as possible before actually lighting off. Check lubrication of equipment having bearings.

--- Oil burners: Must be clean, nozzle must be clean. Check and set electrodes, fittings must not leak, and check operation of burner safety switch.

--- Oil system: Inspect for leaks; make necessary repairs if leaks are present.

--- Strainers: Inspect and clean. Renew if wire mesh is defective.

--- Gas burners: Check the pilot and main gas cock for smooth operation. Check copper tubing for restriction due to kinks and flat spots. Air shutters must operate freely. Linkage must not have excessive amount of lost motion. Burner and main gas valve must be firmly supported. Be sure boiler room has no free gas. If gas is present, ventilate and test piping with soap solution.

### Safety for High Intensity Sound

In central heating plants there is a lot of equipment that produce sound that can be harmful to the human ear. It is now a standard safety practice to issue and use ear plugs in Air Force central heating plants.

### Boiler Start Up

Fill the boiler slowly with properly treated water at a temperature of 70°F to 100°F. The temperature difference between the water and the pressure parts of the boiler should never be greater than 50°F; otherwise severe temperature stresses could be set up. Fill the boiler to just below the middle of the glass on the water column.

Shut the dampers on the induced draft fan; close flue gas control sampling lines; start induced draft fan.

Shut the dampers of the forced draft fan or other air control dampers, then start the forced draft fan.

If regenerative air preheater is installed, start the rotor.

Purge the setting of all combustible gases by circulating air for at least 5 minutes at the rate of about one fourth of the requirements for maximum capacity of the unit.

### Light Off the Boiler

Keep a firing rate sufficient to raise the boiler water from room temperature to the boiling point (212°F) in about 90 minutes. If the unit is filled with hot water, the time can be reduced, but it should not be less than 45 minutes. From this point on, increase the temperature of the water at the rate of 100° per hour. In new boiler installations, check to see if expansion has caused any binding or interference.

Insure that combustion is complete, for incomplete combustion may occur with a cold boiler and can be dangerous.

Check the steam pressure gauge to be sure it is registering. When the steam drum reaches a pressure of approximately 15 psig, close the drum vent valves.

Ease up on the stem of the main steam stop valve to prevent serious expansion stresses. If there is no steam on either side of the valve, lift the valve slightly and gently reseat to make sure the valve is not stuck. Open the drain valve on the boiler side of the main stop valve.

Maintain normal water level by blowing down or feeding water, as required. Be sure the water level is not too high, especially if a superheater is used, since water may be carried into its elements.

Check for leaking gasket joints. If a leaking gasket is found, shut down the boiler, drop pressure, and tighten the joint. Should the gasket persist in leaking, replace it, and repeat the starting sequence.

## Normal Operation

In normal operation, boiler operators have three main responsibilities. The first and most important is to maintain proper water level at all times; the second, to maintain desired steam pressure, irrespective of load changes; and the third, to prevent loss of ignition when burning fuel in suspension (pulverized coal, gas, or fuel oil).

Check the water gauge glass frequently to be sure it is giving a correct indication and that proper water level is being maintained.

Always maintain safe and efficient combustion conditions and correct fuel-air ratios in the furnace. If ignition is lost, care should be taken to assure explosions do not result from ignition of combustion gases when the furnace is relit.

Operational personnel will maintain the equipment to the maximum extent possible. While attending the unit, the operator will perform all maintenance within his capability to assure safe plant operation. If he finds unsafe conditions, he will remain at the plant until the conditions are corrected or the firing equipment is immobilized and the hazard eliminated.

## Operational Checks

Blow down the water column once each shift; before placing a boiler on the line; or when in doubt as to the actual water level in the boiler. Blowdowns help remove scale, dirt, or any solid matter which could plug the gauge glass connections and cause a false indication.

Blow down gauge glasses only when necessary, and if so, blow down gently. Excessive blowdown roughens the glass. Usually, when the water column is blown, the gauge glass is sufficiently cleaned.

## Securing the Boiler

Before shutting down, operate the soot blowers while the boiler is still in operation.

Gradually reduce output of the boiler by cutting down the fuel and air supply. Maintain normal water level.

When the boiler output is reduced to about 30 percent of the rating, change the combustion control from automatic to manual operation.

When the load has been reduced as much as practical with fuel burning equipment provided, shut off the fuel supply.

Continue operation of draft equipment until all fuel accumulations in the furnace have been burned and the furnace is thoroughly purged.

Shut down draft fans and close dampers, including air preheaters and supply dampers.

When steam pressure in the boiler drops below header pressure, close the header. Screw down on the stem of the nonreturn valve. If two hand-operated header valves are used, close both. After the boiler stops steaming, open all drain valves between the nonreturn and header valves.

Cool down the boiler at a rate not exceeding a 100 degree F. drop in saturated boiler water temperature per hour. Excessive stresses in pressure parts can be set up if the rate of pressure and temperature change is excessive.

When the boiler no longer requires any feed, open the valve in the recirculating connection of the economizer.

When the drum pressure drops to approximately 15 psi, open the superheater outlet and nonreturn valve drains. Open the steam drum vent valves. If the boiler loses pressure at a rate faster than allowed (see para above), throttle drain valves as necessary. If a regenerative air heater is provided, stop the rotor when the boiler exit gas temperature drops to 200°F.

### Boiler Safety

When it comes to duties involving the installation, operation, repair, or servicing of boilers, the need for SAFETY cannot be over emphasized. Much progress has been made over the years in the development of safety devices for boilers. There are still many ways, however, in which serious accidents can happen around boilers. A boiler operator or serviceman who is careless in the performance of his job poses a threat not only to his own safety, but to the safety of others. It seems that accidents somehow have a way of happening at a moment we least expect. All the more reason, therefore, for constant alertness and close attention to detail. Don't take chances. BE SAFETY CONSCIOUS.

## EMERGENCY BOILER SHUTDOWN

Practically anything that malfunctions in a central plant can be considered an emergency. The single largest outlay of money in a central plant is for the pressure vessel, and if this vessel is not operating properly, it is probably the most dangerous piece of equipment.

As an operator, you should know all the emergency procedures that apply to your plant and should be able to react calmly and swiftly to any emergency.

### Low Water

Probably the most common emergency is low water in the boiler. When this condition exists, the main consideration is to prevent damage to the pressure parts, especially the steam drum. If a low water condition occurs in boilers fired by fuel oil, gas, or pulverized coal, stop the fires immediately if water does not show in the water glass, and shut off all airflow; then close the steam outlet valves to stop any further delivery of steam. This prevents a sudden pressure drop with a corresponding change in temperature. Shut off the feedwater supply to the boiler.

A slight draft of air through the boiler may tend to stabilize the temperature throughout the pressure parts. The induced fan (or the forced draft, if the unit has no induced fan) can be started up with the control damper almost closed. Since stoker - or hand-fired boilers cannot be shut off quickly, the water will continue to be boiled out. If the water level cannot be maintained, the tubes or boiler plate will probably be damaged. Immediately stop the supply of fuel and air to the boiler, and smother the fire with some noncombustible material such as ashes, taking care to avoid an explosion. Close the steam outlet valves to slow down the drum pressure drop as much as possible. In supplying feedwater to the boiler, you should attempt to maintain a normal water level without drawing too heavily upon the supply to other boilers. Shut off the feedwater supply as soon as the brickwork has cooled sufficiently to prevent injury to the boiler by overheating.

### Furnace Explosions

If an explosion extinguishes the furnace fires, shut off the fuel supply and open the superheater outlet drain valve on superheater installations. Close the boiler main steam stop valve and keep a normal water level. Thoroughly purge the furnace of unburned combustibles and inspect the boiler installation for damage. If no appreciable damage is found, the boiler may be placed back in service. If the water level has fallen below the bottom of the water glass, proceed as for a low-water condition.

### Complete Failure of Ignition (Fuels Burned in Suspension)

If this condition occurs, you should shut off fuel to the burners and open the superheater outlet drain valve in superheater installations. Close the main stop steam valve and maintain a normal water level. Do not change the burner airflow. Purge the setting for 5 minutes with the existing airflow. Place the boiler back in service by following normal start procedures.

### Failure of Combustion Control

If combustion control failure occurs, try to transfer to manual control. If this is successful, continue the operation. If it is not, extinguish the fires and proceed as in a normal shutdown.

### Failure of Feedwater Regulators

When feedwater regulators fail, maintain the water level by manual operation of the control system or by hand manipulation of the bypass valve. In a case of low water, proceed as you would with a low-water condition. If high water occurs, reduce the level by blowdown. Inspect the feedwater regulator and bypass, and eliminate any leaks that are found.

### Draft System Failure

In balanced draft systems, if the induced draft fan fails, stop the forced draft fan and fuel supply. Shut down the boiler. If the forced draft fan fails, continue operation at reduced capacity, if possible. If not, shut down the boiler.

### Priming and Foaming

If priming and carryover are caused by a high-water level, blow down the boiler until the normal operating water level is obtained. Then check the operation of the feedwater regulator and look for a leaking valve in the feedwater system. Priming and foaming are often caused by a high concentration of solids in the boiler water, plus a sudden steam demand. In these cases, reestablish boiler water total solids to safe limits by blowing down and feeding properly treated water. Then check the water treatment operation. A liberal use of the continuous blowdown system sometimes accelerates the return to normal operations.

## FUEL OIL HEATERS

Because they are highly viscous when cold, residual oils no. 5, no. 6 and bunker C must be heated. Heating is usually carried out in two steps. The first heating is done in the oil storage tank itself, or at the tank outlet, to facilitate pumping. A viscosity of 700 SF(Seconds Saybolt Furol) is adequate for pumping. This is obtained at a temperature of about 100°F. The second heating is done in a fuel oil heater located between the pump discharge and the fuel oil burners. Viscosities of 150 SSU (Seconds Saybolt Universal) for mechanical atomizer burners and 200 SSU for steam atomizer burners are usually adequate. These are obtained at approximately 210-220°F. Use the lowest temperature that produces satisfactory operation, avoid overheating. The usual types of fuel oil heaters are steam, electric and below-the-water-line.

### Steam Heaters

As a rule these heaters are of the shell and tube type, with a device to regulate the temperature of oil leaving the heater. The most common device is a thermostatic bulb, immersed in the oil line at the heater outlet, which operates a steam control valve. A small relief valve usually protects most steam heaters from excessive pressure in the oil side. A safety valve of adequate size is also necessary to protect the steam side of the heater from excessive pressures. A steam trap to handle the condensate is necessary.

### Electric Heater

Electric heaters are usually employed when the fuel oil heaters installation is located far from steam lines or when the plant has to be started on residual fuel oil without the assistance of an auxiliary fuel. One type of electric heater consists of a sheathed resistance element, immersed directly in the fuel oil to be heated. A relay actuated by a thermostat interrupts the heater current when the proper temperature is reached.

### Below-The Water-Line Heaters

These heaters are of the shell and tube type. They operate much like the steam heaters discussed already. The main difference is that they use hot water from a steam or hot water boiler instead of steam. Heaters used in steam boiler installation are installed with their center lines below the boiler water line. The boiler supplies hot water to heat the fuel oil. Generally, a gate valve located in the water circulation and oil temperature. The water may be returned directly to the boiler. However, this introduces the possibility of oil entering the boiler. In some installations, it is first passed through an oil separator where any oil entrained from oil leaks is detected and removed. Forced or natural water circulation, depending on the type of installation, is used.

### Electric System Failure

If the electric system fails, start the steam-driven auxiliary equipment. If all auxiliaries are electrically driven and no other emergency source of power is provided a complete shutdown will occur. "Bottle up" the boiler to eliminate the need for boiler feed. While power is being restored, prepare the boiler equipment to resume operation. "Bottling up" the boiler consists of extinguishing the fire, closing up the stop and nonreturn steam valve, stopping the draft fans, and stopping the boiler feed. (With no steam output, the boiler water level will be maintained.) Review the plant installation and determine in advance how water is supplied to the furnace, how air is supplied for combustion, and how the operation of valves and safety devices can be continued if there is an electric power failure.

## PLANT OPERATING LOGS

How would you like to pay a fuel bill of $150,000 a month? If you had a bill of this size, you would surely want to get the heating value that you were paying for. Your base may have a comparable fuel bill that must be paid just as home owners have fuel bills that must be paid. The government pays its bills from public funds, which come from our taxes, and is charged by the Congress to be prudent in the expenditure of these funds. As an aid and management tool to satisfy this congressional requirement, the Air Force has developed reporting procedures to enable it to monitor fuel consumption for utility heating.

These reports begin in the heating plant with us! If we compile a report that is not accurate and factual, we are deceiving ourselves and our supervisors. In this section, we will discuss the required reports and learn how to translate meter information and compute the required information.

The Daily Steam Boiler Plant Operating Log, AF Form 1458, provides the means of recording, on an hourly basis, continuous data that can affect the operation of all central steam plants. The Monthly Steam Boiler Operating Log, AF Form 1464, is completed each day, using the information compiled and computed on the daily log. The instructions for completing these logs are printed on the reverse of each form.

Each operating shift at constantly attended steam plants will fill out AF Form 1458, Daily Steam Boiler Plant Operating Log. The information from this form is posted daily by plant supervisor on AF Form 1464, Monthly Steam Boiler Plant Operating Log. Instructions on the back of these forms tell how to prepare them. Keep the forms neat and legible. Do not recopy, rewrite, or retype them, but submit them as prepared at the plant.

Every plant not constantly attended by an operator must set up a system for recording scheduled operational visits. Operational visits must be long enough to permit observation of a complete cycle. Each time an operator makes a visit, he will enter the appropriate information on AF Form 1458.

SUMMARY

Before lighting off a boiler make certain all valves are open or closed as necessary. Inspect safety valves, check boiler water level and fill boiler to just below 1/2 gauge glass. If boiler is new and has never been in service boil out for 24-48 hours. After lighting fires make certain ignition is maintained. If steam header and distribution system are not under pressure, warm up boiler and system simultaneously. The three main responsibilities of boiler operators are to maintain proper water level, maintain desired steam pressure, prevent loss of ignition. Secure fires when load has been reduced as much as practical

AF Form 1458 is the "Daily Steam Boiler Plant Operating Log." Data should be posted daily to AF Form 1464, "Monthly Steam Boiler Plant Operating Log," from the daily log. Follow instructions from reverse side of logs for the preparation of steam boiler plant logs. The Base Civil Engineer will certify competent operators.

QUESTIONS

1. What is the form number for the Daily Steam Boiler Plant Operating Log?

2. What is the purpose of wearing ear protection?

3. How often are entries made on AF From 1464?

3770 Technical Training Group
Civil Engineering Training
Sheppard AFB, Texas

SG J3ABR54532 001-VI-3

# HIGH TEMPERATURE WATER HEATING SYSTEMS

## OBJECTIVES

Given information, identify the methods of producing high temperature water with 70% accuracy.

Following step-by-step procedures, operate and maintain the high temperature hot water heating system trainer and distribution with insructor assistance.

Using information, maintain a pumping system with instructor assistance.

Given information, list the procedures for performing hydrostatic test on generator and expansion drum with 70% accuracy.

## INTRODUCTION

Until recently the steam heating system was the most commonly used heating system. A number of years ago the use of HTW for large central heating systems was practically unknown in this country and very few attempts were made at that time to consider its application. The high temperature and high pressure created apprehension and concern about excessive cost.

It was left to the engineers of our Armed Forces, who had seen the efficient central heating systems in Europe during World War II, to request a study for application of similar HTW systems for the new Air Force Bases which were then planned or under construction throughout this country.

During the past few years, however, the HTW system has shown a phenomenal growth. It has gone from a very meager beginning in 1952 to a multibillion Btu/hr business at present. A gradual displacement of the steam system by the HTW system may be anticipated in the coming years.

The basic design of a HTW system essentially considers three factors: conversion of steam boilers for use as HTW generators, use of a conventional steam boiler to supply steam to a cascade heater, or special designed HTW generators.

## INFORMATION

### THEORY OF OPERATION

High temperature water (HTW) is the term normally applied to this type of system. HTW systems operate well in excess of the atmospheric pressure boiling point of 212°F. The temperature range for Air Force plants is normally 320°F and above. The pressure is normally 120 psig and above. All HTW systems should be designed for a minimum of 100°F differential between supply and return water temperatures. Normally, the temperature differential is 120°F to 150°F. However, some systems are operating successfully with differentials of 200°F or more. USAF/PRE must approve all designs for HTW systems which operate at temperatures above 400°F.

From the generator, pumps circulate the water through the distribution system. The pumps deliver the water at sufficient head pressure to overcome pressure drops in the distribution circuit and heat-consuming equipment. In some cases, the head pressure is sufficient to provide circulation through the generator.

The most important operating characteristics of the HTW heating systems are: low make-up requirements, high thermal efficiency, low maintenance, safety of operation, and ease of operation and control.

#### Low Make-Up Requirements

The HTW system is completely closed; the only water wastage is the normal leakage from pump glands and valve packing. Therefore, it consumes very little water when operating. This means minimum make-up water requirements and practically eliminates boiler blowdown.

## Thermal Efficiency

The closed recirculation system operates at a high thermal efficiency. All heat not used by consumers or lost through pipe radiation is returned to the boiler plant. Since infrequent boiler blowdowns are required, heat loss from that source is minimal. Also, the thermal "flywheel" effect, resulting from the large heat storage capacity of high temperature water permits the system to accumulate generated heat and evens out the heating load on the boiler. The sudden changes in firing rates which produce poor combustion and high stack gas temperatures are therefore eliminated and boiler efficiency is increased. Table 1 compares the heat storage capacity of water and steam for various pressures and temperatures. At 50 psig with the temperature at 298°F, water contains 90.4 times the amount of heat that steam does (15,360 divided by 170 equals 90.4).

| Gauge Pressure Psi | Temperature °F | Total Heat Content BTU/cu ft | | Ratio: Water/Steam |
|---|---|---|---|---|
| | | Water | Steam | |
| 50 | 298 | 15,360 | 170 | 90.4 |
| 60 | 308 | 15,840 | 203 | 78.0 |
| 70 | 316 | 16,260 | 229 | 71.0 |
| 80 | 324 | 16,670 | 255 | 65.4 |
| 90 | 331 | 17,000 | 281 | 60.5 |
| 100 | 338 | 17,320 | 306 | 56.6 |
| 110 | 344 | 17,600 | 332 | 53.0 |
| 120 | 350 | 17,870 | 358 | 49.9 |
| 130 | 356 | 18,170 | 384 | 47.3 |
| 140 | 361 | 18,380 | 410 | 44.8 |
| 150 | 366 | 18,610 | 434 | 42.9 |
| 160 | 371 | 18,830 | 461 | 40.9 |
| 170 | 375 | 19,040 | 486 | 39.2 |
| 180 | 380 | 19,220 | 511 | 37.6 |
| 190 | 384 | 19,400 | 537 | 36.1 |
| 200 | 388 | 19,570 | 562 | 34.8 |
| 210 | 392 | 19,750 | 588 | 33.6 |
| 220 | 396 | 19,920 | 613 | 32.5 |
| 230 | 399 | 20,080 | 639 | 31.4 |
| 240 | 403 | 20,240 | 664 | 30.5 |
| 250 | 406 | 20,390 | 690 | 29.6 |
| 260 | 409 | 20,530 | 716 | 28.7 |
| 270 | 413 | 20,670 | 741 | 27.9 |
| 280 | 416 | 20,800 | 767 | 27.1 |
| 290 | 419 | 20,920 | 792 | 26.4 |
| 300 | 422 | 21,040 | 818 | 25.7 |

Table 1. Heat Storage Comparison of HTW and Steam

## Maintenance

Maintenance required is minimal. Since the same water is recirculated, the system is always filled with noncorrosive, treated water and corrosion and scaling do not occur. This reduces repair and maintenance costs. Costs are further reduced by the fact that HTW systems have no traps and reducing valves to maintain.

## Safety Feature of HTW

HTW is actually safer than steam under similar conditions. As an example, if a 1/2 inch HTW pipe containing 400°F water at 200 psig were to rupture, the end result at a distance of 18 inches from the break would be water at approximately 120°F, and at a negligible pressure. Water at 400°F is not in a natural state at atmospheric pressure. Therefore, water from a HTW line break must change state or flash to steam. The amount of heat required to change wat[illegible] to steam is greater than the total heat content of a given amount of HTW. In theory, if a pound of 400°F water is exposed to the atmosphere, 75 percent of that pound must release its total heat content to flash the remaining 25 percent of a pound to steam. This steam is aerated and mixed with the cooled 75 percent of a pound of water which reduces the steam to condensate at a temperature of approximately 120°F. An added benefit is gained by the ~~water~~ exiting the break as a vapor or steam. This vapor forms as it is exiting the pipe. Steam occupies a greater space than water; in fact, this pound of water will expand 265 times when released to the atmosphere. This expansion throttles the break area, limiting the amount of water that can pass through the opening. A steam system, on a comparison basis, expands only 13 times and DOES NOT CHANGE STATE. In other words, the full velocity and temperature of steam is altered only slightly in a break. Therefore, HTW is safer than steam in the event of line rupture.

### Ease of Operation and Control

Another advantage of the HTW system is the simplification of valves and fittings. There are no traps, drips or pressure-reducing valves, and feedwater treating equipment is small and simple. Uniform temperature is maintained as easily during normal operation as during peak loads.

## METHOD OF GENERATING HTW

There are three basic methods of generating HTW. These are: converted steam boilers, cascade heaters (direct contact), and specially designed HTW generators.

### Converted Steam Boilers

This method utilizes an existing steam boiler converted to HTW. It may use the existing steam drum (water-tube boilers) as an expansion drum or an expansion drum may be externally mounted. Fire-tube or water-tube boilers may be used; however, best results are normally obtained using water-tube boilers. Figures 47, 48 and 49 illustrate the various conversion of steam boilers to HTW.

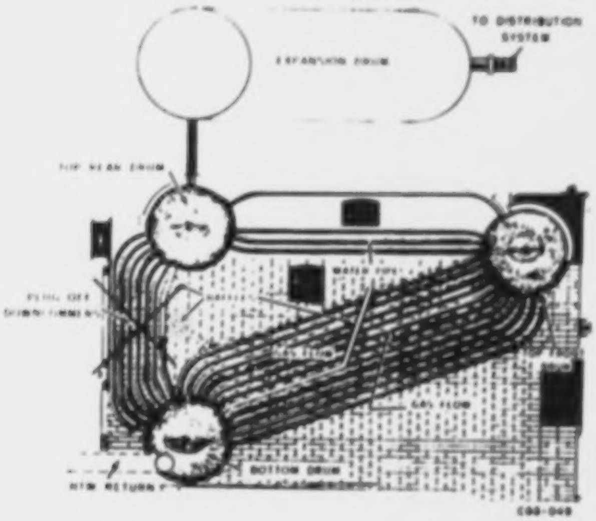

TO DISTRIBUTION SYSTEM
EXPANSION DRUM
TOP STEAM DRUM
PLUG OFF DOWNCOMERS
GAS FLOW
BOTTOM DRUM
HTW RETURN

Figure 47. Converted Steam Boiler, External Expansion Drum (Flooded Boiler)

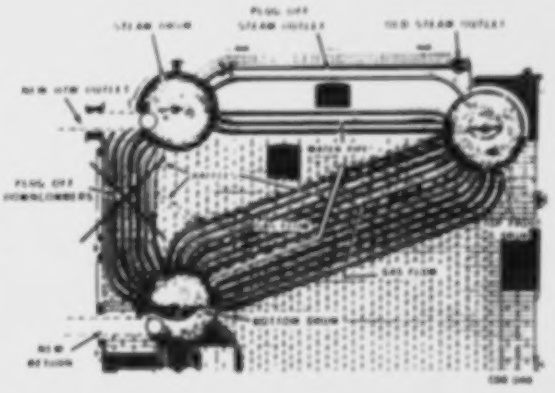

STEAM DRUM
PLUG OFF STEAM OUTLET
OLD STEAM OUTLET
NEW HTW OUTLET
PLUG OFF DOWNCOMERS
GAS FLOW
BOTTOM DRUM
NEW RETURN

Figure 48. Converted Steam Boiler, Integral Expansion Drum

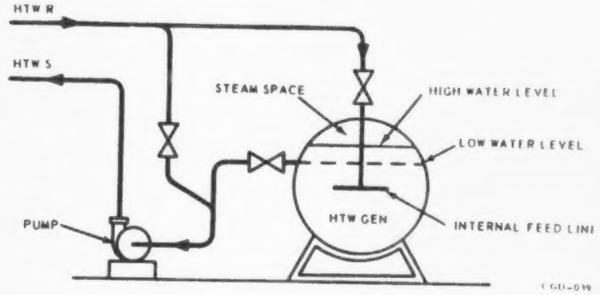

HTW R
HTW S
STEAM SPACE
HIGH WATER LEVEL
LOW WATER LEVEL
PUMP
HTW GEN
INTERNAL FEED LINE
CGD-019

Figure 49. Converted Fire Tube Boiler, HTW Generator

DESIGN PROBLEMS ENCOUNTERED IN CONVERTED STEAM BOILERS. The primary problems to consider when converting steam boilers to HTW are: balanced distribution through each tube circuit, positive circulation through each tube circuit, the prevention of steam bubble formation in the tubes, and thermal shock to the generator when the relatively cooler return water or the makeup water is introduced into the generator.

EFFICIENCY OF CONVERTED STEAM BOILERS. Steam boilers converted to HTW generators are far less efficient than are specially designed HTW generators. Most steam boilers are designed for natural circulation, therefore, they have larger tubes. Larger tubes do not permit as high degree of heat transfer as do the smaller, forced-circulation tubes of specially designed HTW units. The tubes of a steam boiler are spaced relatively wider apart and the combustion chambers contain large amounts of refractory lining. Neither of these conditions are encountered in specially designed HTW units.

### Cascade Heater

Cascade or direct-control heaters are used as a means of generating HTW by mixing high-pressure steam directly with water. Steam is supplied by an independently-fired steam boiler. The pressure of the steam determines the temperature of the HTW. To meet the minimum HTW temperature requirements, the steam must be supplied to the cascade at approximately 120 psig.

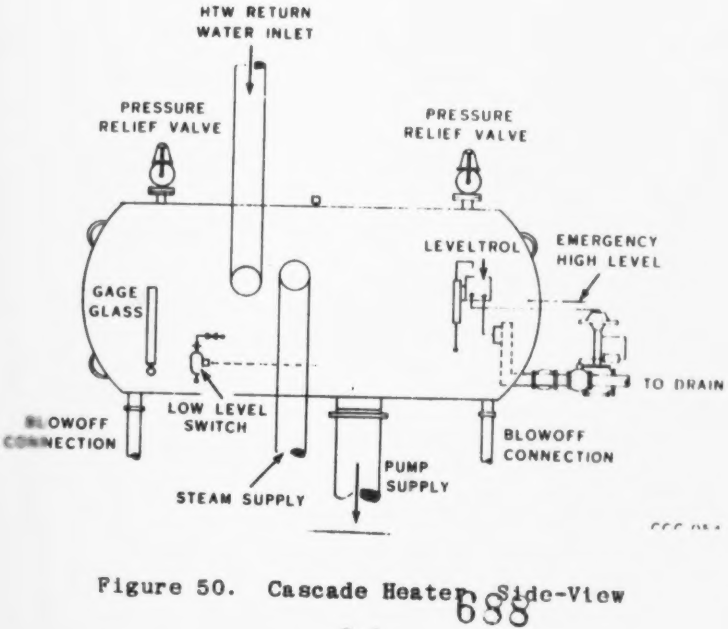

HTW RETURN
WATER INLET
PRESSURE
RELIEF VALVE
PRESSURE
RELIEF VALVE
LEVELTROL
EMERGENCY
HIGH LEVEL
GAGE
GLASS
TO DRAIN
LOW LEVEL
SWITCH
BLOWOFF
CONNECTION
BLOWOFF
CONNECTION
STEAM SUPPLY
PUMP
SUPPLY

Figure 50. Cascade Heater, Side-View

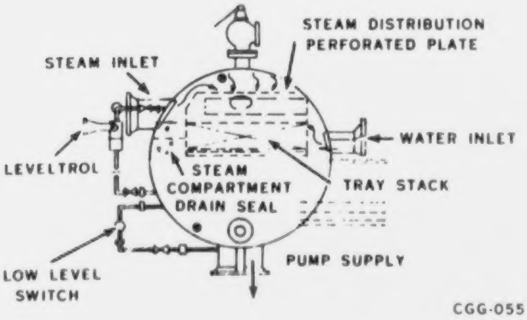

STEAM DISTRIBUTION PERFORATED PLATE
STEAM INLET
WATER INLET
LEVELTROL
STEAM COMPARTMENT DRAIN SEAL
TRAY STACK
PUMP SUPPLY
LOW LEVEL SWITCH
CGG-055

Figure 51. Cascade Heater, End-View

Specially Designed HTW Generators

High temperature water generators are of two main types: forced circulation and natural circulation.

FORCED-CIRCULATION GENERATORS. Forced-circulation generators discharge high temperature hot water, at specified saturation temperature and pressure, to a pressurized expansion drum that feeds the system circulating pumps. Positive circulation of boiler water is assured by a centrifugal pump which circulates the water at high velocity through all tubular circuits, regardless of the firing rate. A separate boiler pump or the system circulating pump may be used. Figure 55 illustrates one type of a forced-circulation HTW generator.

Forced circulation provides a higher overall heat transfer per unit surface area. Therefore, in general, forced circulation boilers have smaller overall heating surfaces than natural circulation boilers of the same rating.

The following are forced flow generators specially designed for HTW use:

CONTINUOUS UPWARD FLOW GENERATORS. This generator has its inlet located on the bottom rear of the unit (figure 52). The water enters the tube circuits and progresses in a continuous upward movement to the generator outlet.

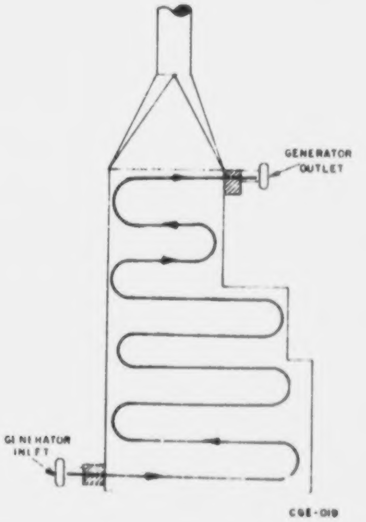

GENERATOR OUTLET
GENERATOR INLET
CGE-010

Figure 52. Continuous Upward Flow Circuit

**COUNTERFLOW ECONOMIZER GENERATORS.** These units receive the return HTW through the top rear of the generator and circulate it down through an economizer. The economize absorbs heat from the hot flue gases which would otherwise be wasted to the atmosphere. Figure 53 illustrates the flow path of this type of generator

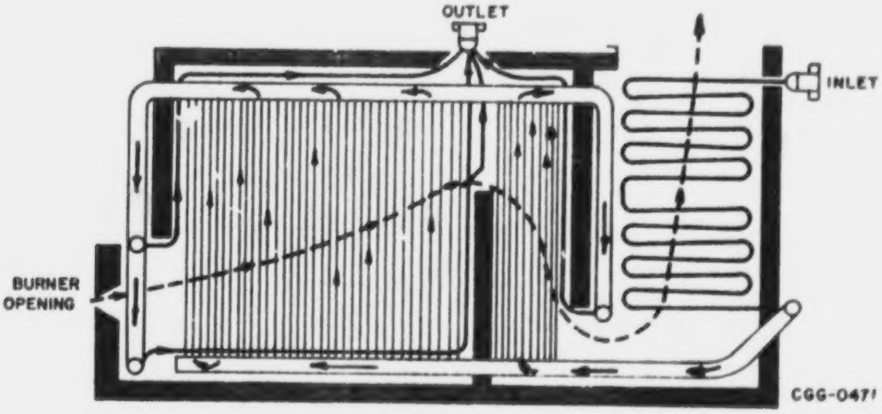

OUTLET
INLET
BURNER OPENING
CGG-0471

Figure 53. Counterflow Economizer HTW Generator

**UPWARD FLOW ECONOMIZER.** This generator is similar to the counterflow economizers except the return water enters at the top front of the unit and passes upward through A (the furnace roof circuit). Figure 54 shows the flow path of this generator. Flow is from A through F, in alphabetical order. C is the convection tube bank circuit and E the furnace and open pass circuit.

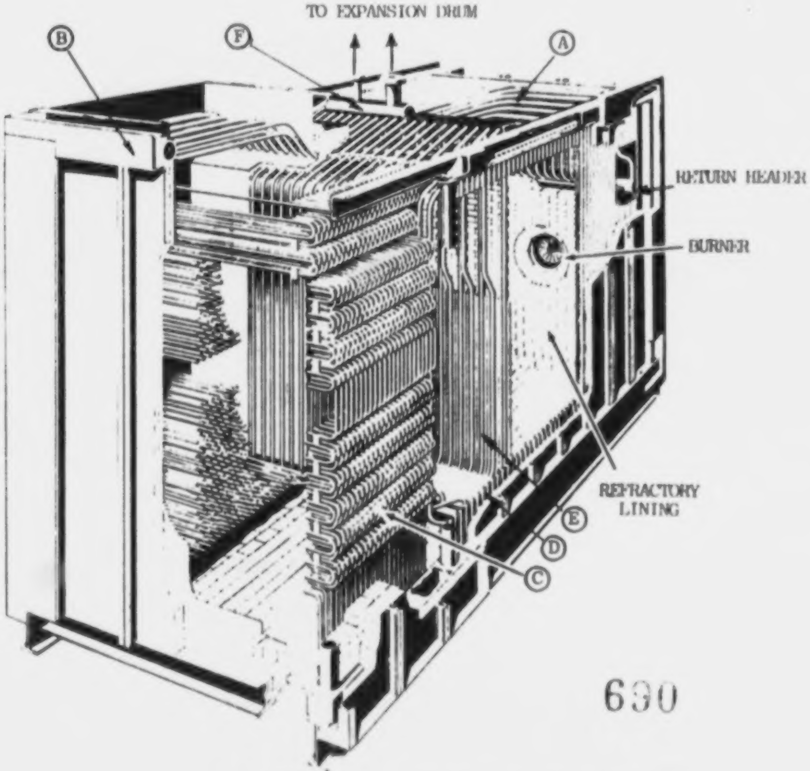

TO EXPANSION DRUM
Ⓑ
Ⓕ
Ⓐ
RETURN HEADER
BURNER
REFRACTORY LINING
Ⓔ
Ⓓ
Ⓒ

Figure 54. Upwardflow Economizer

NATURAL CIRCULATION GENERATORS. In natural circulation boilers, the buoyancy produced when water absorbs heat starts and maintains the circulation. The circulation, therefore, varies with the rate of firing or the local rate of heat transfer. To prevent restriction of circulation, these generators usually contain larger tubes than do forced circulation boilers. In this generator, downcomers (where water circulates in a general downward direction) should be heated less intensely than the risers (where water circulates in a general downward direction) should be heated less intensely than the risers (where water circulates in an upward direction); otherwise, circulation may be affected. Because of these features, natural circulation boilers are larger than forced circulation units. When natural circulation boilers are used with high temperature water systems, do not let the forced circulation in the external circuit interfere with the natural circulation inside the generator.

## METHODS OF PRESSURIZATION

There are two basic methods of pressurizing a HTW system: (1) the saturated steam cushion method, and (2) inert gas pressurization. Pressurization is necessary to keep the HTW in a liquid state. This is accomplished through use of an expansion drum. The expansion drums used in low and medium temperature water are similar to those used in HTW, in as much as they both allow for expansion. However, after this point, they are quite different, both in size and function. The different types and sizes of expansion drums will be discussed under each method of pressurization.

### Steam Cushioned Pressurized System (Figure 55)

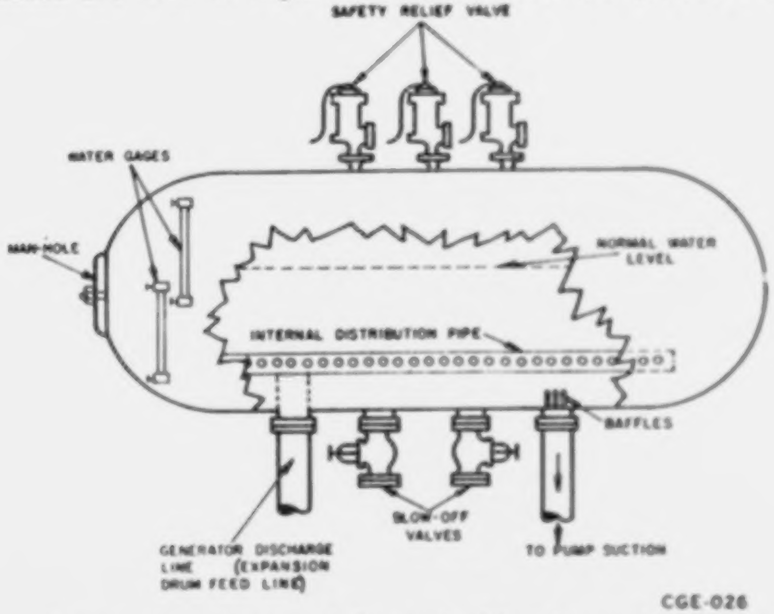
Steam pressure at the saturated water temperature is used directly to impose a pressure cushion in an expansion drum. Steam is flashed to maintain a constant pressure within the drum.

To permit free vapor release, the expansion drum is located above the generator, with sufficient height to furnish a reasonable net positive suction head for the circulating pump.

The drum is generally sized to handle changes in water volume resulting from normal load changes--not from the cold condition, as this extreme occurs only when starting up cold.

As a rule, the highest permissible water level for horizontal drums is 75 to 78 percent of the tank diameter. The minimum drum water level should be at least three to five feet above the boiler header.

Two or, at the most, three expansion drums may be installed in series, if equalizing steam and water lines are used to adjust the water level and pressure difference between the tanks.



CGE-026

Figure 55. Saturated Steam Cushion Expansion Drum

In operation, the drum is filled approximately half full of water and the generator is fired to heat up the water. A vent valve is opened on the top of the drum and a portion of the hot water flashes to steam. Once a steam cushion is established, the vent valve is shut off. The HTW flowing from the generator into the expansion drum expands and pushes against the steam cushion. The steam cushion in turn pushes back against the water, pressurizing the system. The pressure in the expansion drum is equal to the saturation temperature of the water. Referring to table 2, if the generator is operating at 380°F, then the expansion drum pressure will be 195.77 psia. This pressure-temperature relationship will always remain constant. If the generator output temperature drops to 370°F, then the water level in the expansion drum will decrease and the resultant steam pressure will be 173.37 psia. Air is not used as a means of pressurization because oxygen is corrosive to drum surfaces. The HTW leaves the generator and flows through the expansion drum; therefore, the drum is always hot and should be insulated accordingly.

| Temp F | PSIA |
|---|---|
| 300 | 67.013 |
| 320 | 89.66 |
| 340 | 118.01 |
| 350 | 134.63 |
| 360 | 153.04 |
| 380 | 195.77 |
| 400 | 247.31 |
| 420 | 308.83 |
| 440 | 381.59 |
| 460 | 466.9 |
| 480 | 566.1 |
| 500 | 680.8 |
| 520 | 812.4 |
| 540 | 962.5 |
| 560 | 1133.1 |
| 580 | 1325.8 |
| 600 | 1542.9 |
| 620 | 1786.6 |
| 640 | 2059.7 |
| 660 | 2365.4 |
| 680 | 2708.1 |
| 700 | 3093.7 |
| 705.4 | 3206.2 |

Table 2. Saturation Temperature

### Inert Gas Pressurization

The inert gas system normally uses nitrogen as the pressurizing gas. The expansion drum is connected to the suction side of the HTW pump by means of a balance line. The pressurizing gas is fed into the top of the expansion drum. The relief valve is located below the minimum water level for two reasons: (1) to provide a liquid seal (water) against the seat rather than exposing it to the inert gas; (2) in the event of excessive pressure the lifting of the safety valve would drain the gas cushion. The expansion drum is normally installed vertically to reduce the area of contact between the inert gas and water. Unlike the saturated steam cushion, the inert gas expansion drum may be located wherever it is most suitable in the central plant. These systems are normally pressurized to a minimum of 40 psig above the saturation pressure. The pressure limiting factor is based on the rating of the fittings, valves, piping and equipment. The inert gas expansion drum pressure must be of sufficient magnitude to prevent steam forming in the HTW generator(s) under all conditions. This is critical since gas-pressurized systems do not have steam separating capabilities or safety valves to evacuate the steam generated.

FIXED QUANTITY GAS CUSHION. The fixed quantity inert gas cushion is the simplest type of gas pressurization system. The pressure within the gas space varies with changes in the water level in the expansion drum. As the normal system water temperature increases, the expansion of the system water into the drum compresses the gas, raising the system pressure. A reversal of this operation takes place on a drop in the normal system water temperature. The pressure is permitted to vary from a minimum point above saturation to a maximum, which is determined by the ratings of the materials used in the system.

VARIABLE GAS QUANTITY CUSHION. This is another method of gas pressurization. The inert gas is relieved from the expansion drum on a rise in water and is either wasted or recovered; in a low-pressure gas receiver. A gas compressor pumps the low-pressure gas into a high-pressure receiver for storage. When the water level drops in the expansion drum, the control cycle adds inert gas either from bottles or from the high-pressure receiver, to the expansion drum to maintain the required pressure. The gas wastage system is more costly to operate, but less expensive to install. The gas recovery system is more complicated and higher in initial cost. Normally, the gas recovery system is more applicable to large central plants, where the higher installation costs can be justified in nitrogen gas savings.

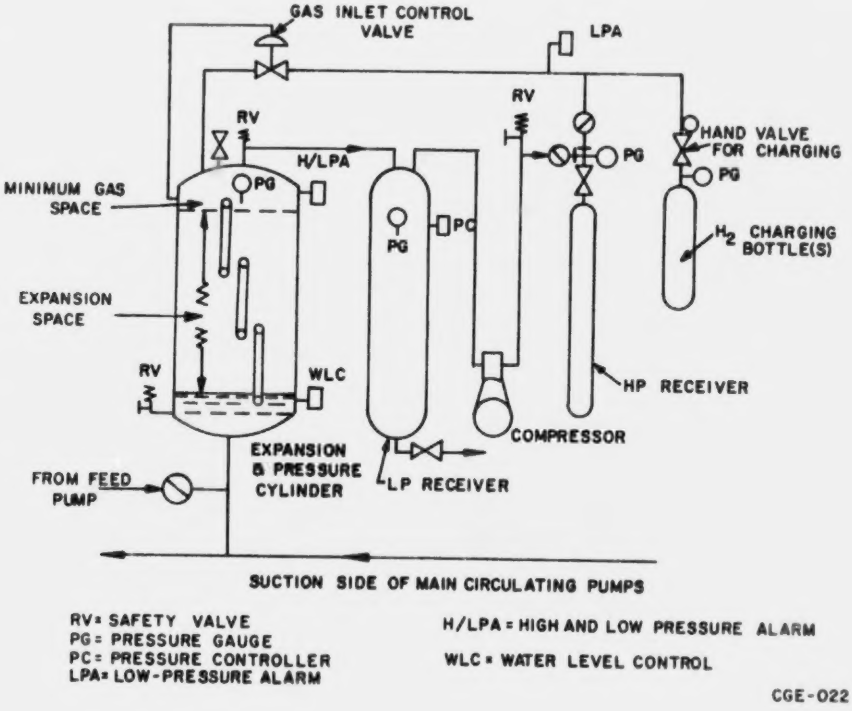

GAS INLET CONTROL VALVE
LPA
RV
RV
H/LPA
HAND VALVE FOR CHARGING
PG
PG
PG
PG
PC
MINIMUM GAS SPACE
$H_2$ CHARGING BOTTLE(S)
EXPANSION SPACE
RV
WLC
HP RECEIVER
COMPRESSOR
EXPANSION & PRESSURE CYLINDER
LP RECEIVER
FROM FEED PUMP
SUCTION SIDE OF MAIN CIRCULATING PUMPS
RV= SAFETY VALVE
PG= PRESSURE GAUGE
PC= PRESSURE CONTROLLER
LPA= LOW-PRESSURE ALARM
H/LPA = HIGH AND LOW PRESSURE ALARM
WLC = WATER LEVEL CONTROL
CGE-022

Figure 56. Variable Gas Quantity Cushion

PUMP PRESSURIZATION. Pump pressurization in its simplest form consists of a makeup tank and forcing it into the system. The pressure regulating valve continuously bleed water from the system back to the makeup tank, and the cycle is repeated. This method is normally restricted to small process heating systems, but it may be used for temporary pressurization of a larger system to avoid shutdown during inspection of the expansion drum. In larger HTW plants, pump pressurization is generally combined with a fixed quantity gas compression tank, which acts as a buffer. When the pressure rises above a preset valve in the buffer tank, a control valve opens to relieve water from the balance line into the makeup storage tank. When the pressure falls below a preset second valve, the feed pump is started automatically to pump water from the makeup tank back into the system. The buffer tank is designed to absorb only the limited expansion volume which is required for the proper functioning of the pressure control system. It is usually relatively small. The makeup storage tank is usually closed and pressurized with one to five pounds of nitrogen, to prevent oxygen entry into the HTW system. The gas pressurization in this low-pressure system is normally the variable gas quantity, with venting to the atmosphere (wasted gas).

## PUMPING SYSTEMS

Pumping systems are used in HTW to circulate the water through the generator and distribution system and to maintain the system pressure above the saturation point. The pumps used are electric-motor driven, single-stage, centrifugal-force pumps. The pumps may be either constant or variable speed, and end-suction, top-suction or split-casing.

Some installations use large pumps for winter operation (high flow rates) and considerably smaller pumps for the reduced flow requirements of summer heating loads. Many designers, engineers and operators prefer variable speed zone and system pumps. Variable-speed pumps are popular because they can be adjusted and operated at the current system flow requirement. This factor reduces the amount of horsepower used by the pump, as compared to a constant-speed pump, which operates at maximum output at all times. The speed of variable-speed pumps may be adjusted through the use of transmission, coupling or regulating the amperes going through the drive motor. Figure 57 illustrates a constant-speed pump and figure 56 illustrates a variable speed pump.

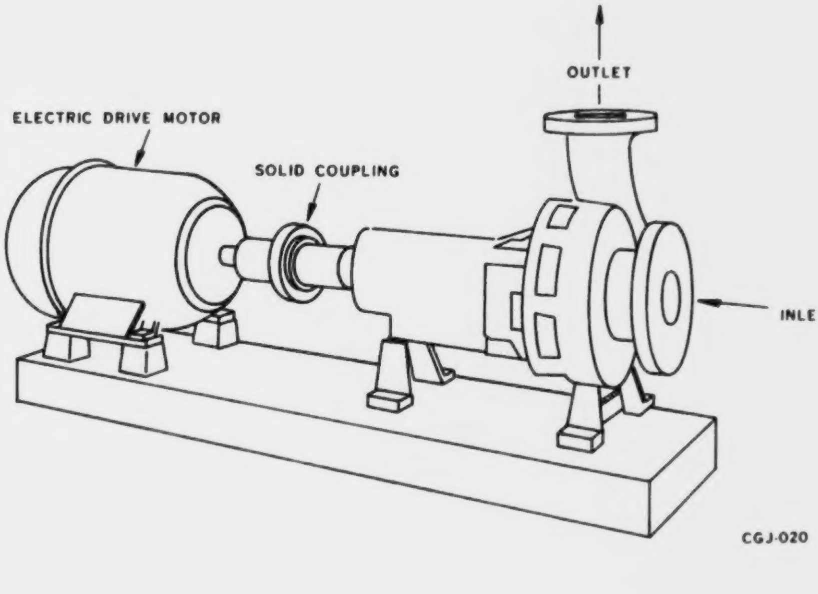


Figure 57. Constant-Speed Pump

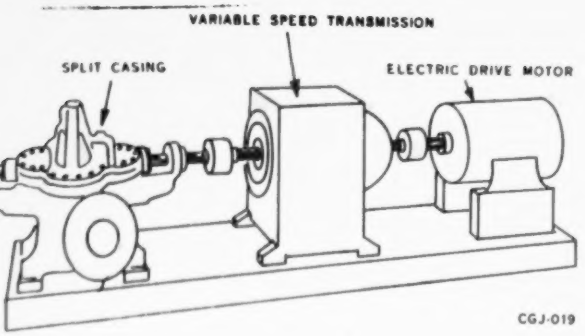


Figure 58. Variable-Speed Pump

All HTW circulating pumps use oil (not grease) for lubrication, and are equipped with water-cooled casings and oil pumps. These pumps may use either open- or closed-face impellers, figure 59; however, closed-face impellers with wearing rings are normally used for HTW. The water from the cooling connections is piped to the face of the mechanical seal to flush off any abrasives which may be encountered, or directly into the packing of pumps equipped with packing and stuffing boxes. This helps to cool the packing and reduce wear of the pump shaft. In most cases, the cooling water is drawn from the base cold water supply and after cooling the pump, it is piped to drain. Some installations provide refrigerated or cooling tower means of cooling the water and recover and recycle the used water. The initial and operating costs of such a system should be closely examined before such a system is installed.

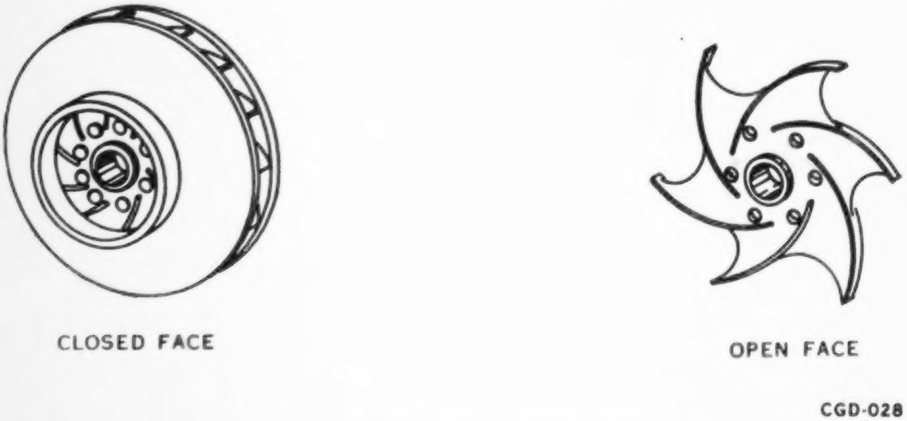


Figure 59. Impellers

Combined Pumping System

This system uses one pump to circulate water through the distribution system and the generator(s). When used on a saturated steam cushion system the circulating pump is installed directly below the expansion drum on the HTW supply, to provide the necessary static head required. Most systems are designed with sufficient head to keep the water from flashing; however, should flashing occur, provisions are available to blend return water with the supply water to cool the latter below the saturation point. The circulating pump discharge is sufficient to raise the system pressure above the saturation point and maintain such pressure throughout the entire distribution system. When the combined pumping system is used on the inert gas system, it is normally installed in the system return line immediately after the expansion vessel. Gas-pressurized systems rarely incur flashing in the circulating pump because of the lower return water temperature and the high artificial head created by the expansion vessel.

## Separate Pumping System

This system uses a pump to circulate water through each generator and one or more pumps to circulate water through the distribution system, figure 61. The generator pump is normally plumbed to facilitate cross-utilization of the pumps between the generators. The system or zone pumps are installed directly below the expansion drum on the saturated steam cushion pressurized system and directly below the generator discharge header on each inert gas pressurized system

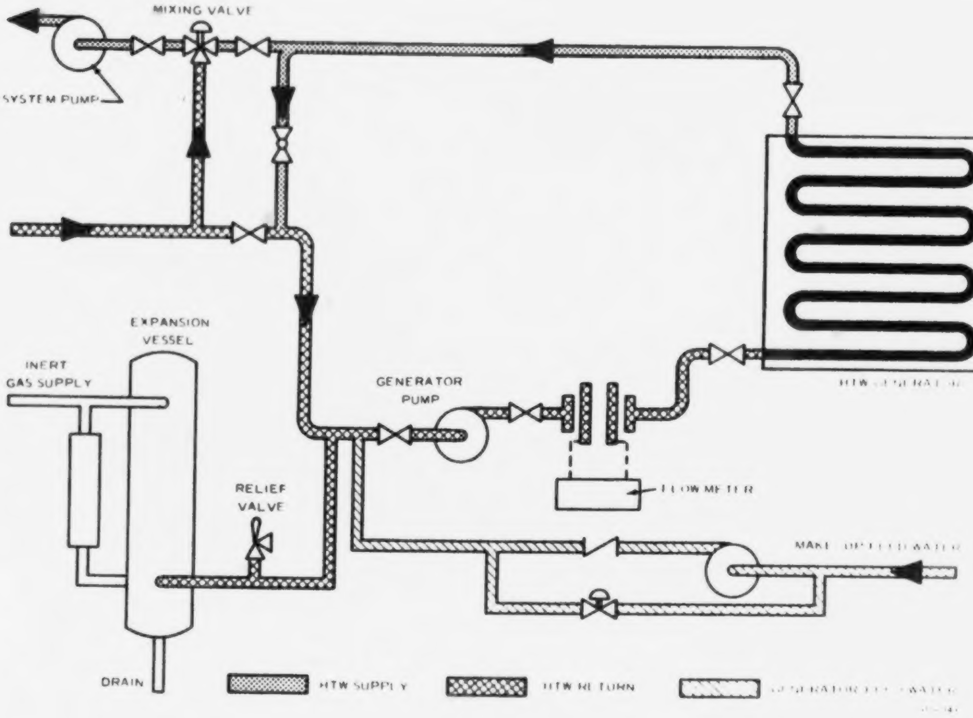

MIXING VALVE
SYSTEM PUMP
EXPANSION VESSEL
INERT GAS SUPPLY
GENERATOR PUMP
HTW GENERATOR
FLOWMETER
RELIEF VALVE
MAKE-UP FEEDWATER
DRAIN
HTW SUPPLY
HTW RETURN
GENERATOR FEEDWATER

Figure 60. Separate Pumping System, Inert Gas Cushion

## Filling and Emergency Pump

When the makeup feedwater pump is not large enough, a cold-water filling pump with a capacity ranging from 100 to 200 gpm is used to fill the sytem. These pumps are also used in case of line break or other emergency. This pump delivers water from either the raw water supply or the treated water makeup tank to the expansion tank, return header and generator. When the pump is used as a standby for the makeup pump or for emergencies, its suction is also connected to the feedwater heater.

## Makeup Feed Pumps

These pumps are normally electrically driven plunger (reciprocating) type pumps. The suction is connected to the feedwater heater and the discharge is piped either to the expansion tank or the return header, depending on the design of the system. The capacity of these pumps is normally determined by the time required to fill the expansion tank from the lowest to the highest design operating levels.

Concentrated efforts have been made to keep HTW systems and controls as simple as possible and still obtain the desired results. To a large degree, this has been accomplished; however, many of the components are peculiar only to HTW, while others apply to both steam and hot water boilers in general.

### Mixing Connection

This connection, "A" in figure 61, prevents flashing in the circulating pump by cooling the water from the expansion drum. This is accomplished by piping relatively cooler system return water into the supply water, immediately before the circulating pump suction.

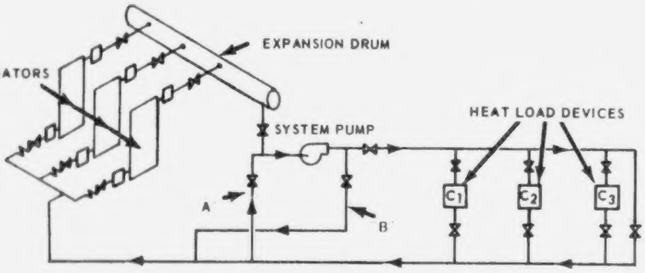


Figure 61. Multiple Generator HTW Combined Pumping System

### Bypass Connection

This connection is used in all HTW combined pumping systems. It is actuated by a preset minimum amount of water passing through the generator, which is detected by a minimum flow control or a pressure differential control. The low flow through the generator is detected, the bypass connection opens and de-routes a portion of the HTW supply from the circulating pump discharge into the generator inlet.

### Differential Pressure Control

Each HTW boiler should have either a differential pressure or a minimum flow control or cut off firing when the pressure difference between boiler inlet and boiler outlet falls below a preset minimum. If a pump fails, this control will prevent the boiler from burning out because of insufficient circulation. The control should be connected to measure the difference in pressure between the suction and discharge headers of the boiler.

### Minimum Flow Control

This control provides the same type of protection as the differential pressure control described above; however, it is motivated by a preset minimum flow through the boiler rather than by a low pressure difference across the boiler. It is generally connected to a flow meter in the boiler feedwater inlet line.

### Thermocouple Control (Thermoelectric Pyrometer) (Figure 62)

All HTW generators should be equipped with thermocouple controls designed to secure the generator in the event of excessive temperatures. Two or three (depending on generator tube circuit design) thermocouple leads are installed on the two or three most critical tubes in the generator. (The criticality of a generator tube is determined by the amount of radiant heat applied to it.) The cold junction of the thermocouple is attached to a millivoltmeter and control switch. This control operates on the amount of millivolts generated by the thermocouples. The more heat applied to a thermocouple, more millivolts it will generate. When the millivoltmeter measuring needle, "A" in figure 112 reaches the set needle, "B" in figure 62, it will trip the safety switch which will secure the fires immediately. Any one of the thermocouples can trip the safety switch, which is normally set by approximately 15°F above the generator set operating temperature.

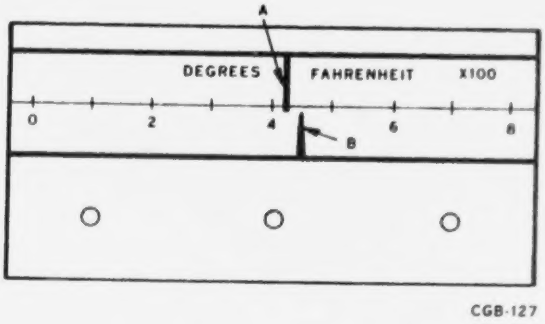


Figure 62. Thermocouple Control

Expansion Drum Water Level Control

Usually HTW systems have high and low level controls to stop firing equipment when the water in the expansion drum reaches abnormal predetermined levels. In any case, the circulating pumps continue in operation.

Flame Failure Control

This control operates in the same manner as that described for steam boiler operations. It usually consists of safety shut-off valves to supervise pilot and flame.

Air-Flow Switch

Package HTW boilers usually have programming control which includes an air-flow switch to insure shutdown and proper purge of the unit in event of fan failure.

High-Limit Pressure Control

This control shuts down the unit when a preset high pressure is reached.

BTU-Meter

The instruments and meters used in HTW installations are similar to those described for steam plant operation. There is, however, one special type of meter which is generally used in installations of more than 20 million BTU per hour output. It is the BTU-meter which is usually to integrate the heat flow in the system. One component of the meter measures the instantaneous temperature difference between the flow and return lines, usually recording the temperatures simultaneously, while another component measures the instantaneous temperature difference between the flow and return lines, usually recording the temperatures simultaneously, while another component measures the instantaneous rate of flow in the return line with an orifice or venturi meter. The BTU-meter obtains and integrates instantaneous products of the temperature difference and flow. The multiplication and integration show the heat energy delivered to the system or removed by the heat consumer across which the meter is connected; the flow meter component simultaneously records the flow.

## DISTRIBUTION SYSTEMS

In general, the methods described for steam distribution are used to distribute HTW.

However, the following specific considerations apply to HTW systems aboveground. System piping must be protected against snow and rain with metal or tar paper coverings.

Underground system piping may be located from 3 to 6 feet below the ground level. Some engineers oppose using the lines for snow melting and recommend that they be located below the frost line. It has been found, however, that lines located only three feet underground do not freeze, even when out of operation for many hours.

### Valves

All globe and gate valves used for HTW service, except at high-pressure installations, should be made of cast steel in the 300-psi class. Valves larger than two inches are usually of the outside screw and yoke type with bolted bonnets. (Smaller valves may be equipped with screwed bonnets.) The stuffing boxes should be large and deep. Valves that are smaller than two inches should have at least four or five rings of U- or V-shaped packing; larger valves should have at least six rings. Inlet and outlet valves of HTW generators and expansion drums--and usually any valve larger than eight inches--should have a bypass valve.

EXPANSION OF STEEL OR WROUGHT IRON PIPE WITH TEMPERATURE

| Pipe Temperature (°F) | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |
|---|---|---|---|---|---|---|---|---|---|
| Expansion in inches per 100 feet length of pipe (from 0°F to pipe temperature shown) | 0.6 | 0.9 | 1.3 | 1.3 | 2.2 | 2.6 | 3.0 | 3.3 | 4.0 |

Figure 63

### Expansion Loops, Expansion Joints, and Anchors

Piping expands when the temperature increases; consequently, the ASA establishes the units of expansion for steel or wrought iron pipe, which are given in figure 63. From figure 64, we see that a 100-foot steel or wrought iron pipe expands 3 inches when the temperature changes from 0°F to 400°F.

Expansion loops or expansion joints provide for thermal expansion. Expansion loops, consisting of U-bends, are usually located midway between two anchor points. Corrugated expansion joints are sometimes used to save space. When they are used, they ordinarily have guides to insure that they are aligned properly. Backing-up rings limit the travel of each corrugation. Expansion joints should be accessible so that their alignment can be checked at regular intervals.

Anchors are installed in combination with expansion loops and expansion joints to control and guide the expansion piping systems. The anchors must be strong enough to support the full unbalance pressure of the water and extension strains, as well as the weight of the water-filled line. If an anchor is loose the expansion or contraction of the pipe can cause failure of the expansion joint or cause the flanged or welded fittings used in the HTW system to become damaged.

### Pipe and Installation

Pipe, fittings and insulation are much the same for HTW systems as they are low-temperature hot-water systems, except that more strength is required in the pipe and fittings, and greater thickness is needed in the insulation.

## Piping

Steel or wrought iron pipe of Schedule 40 or standard thickness is normally used. Usually, welded connections and seamless pipe are used to prevent leaking, but flanges are required for valves larger than six inches. When piping is designed and installed, allowance must be made for the thermal expansion that occurs when the system goes from cold to maximum operating temperature. The piping should be adequately supported and should have vented high points, drainable low points, and connections wherever required.

## Insulation

All heating plant supply and return lines should be insulated with a double thickness of insulation suitable for the temperature. Flanges, valves and pumps should also be insulated to prevent heat loss and possible injury to operating personnel.

## Maintenance

The maintenance of a HTW system pump consists primarily of cleaning, aligning and lubricating. If the pump has water-cooled gearings, it must have the proper amount of water available for cooling. If major repairs are required, follow the step-by-step procedures provided by the pump manufacturer.

## Thermometers and Pressure Gauges

Thermometers (preferably dial type) or the thermometer wells should be installed in the flow and return pipes, the pump suction and discharge lines, and at any other point of major temperature change or where temperature is important in operating the system. Pressure gauges should be installed in the pump discharge and suction lines at locations where the pressure readings assist in efficient operation and maintenance. It is desirable to have both thermometers and gauges installed in the piping at the entrance to each building, at each hot-water converter, or at each steam converter. Any one of these setups allows the operator to quickly determine the temperatures and pressures in the system, and to adjust the equipment accordingly.

## Critical Features

Critical features while the distribution system is being warmed up. Observe the following points: the action of expansion joints or loops, the action of supports, anchors, hangers, etc., free expansion of heaters and piping in the expected directions. If restraint is noted, shut down the system and correct.

Forced circulation HTW generators consist only of tubes and headers, and they have no pressure vessels such as a steam or "mud" drum. The tubes (convectors) in the convection section of the furnace portion of the generator are the weakest link in the system's circuits. The thin gauge metal of the tubes collapses from overheating when liquid contact is lost on the interior of the tubes for as short a time as two minutes. It is, therefore, not possible to develop high steam pressures within the system because the tube failure occurs in such a short time. The release of water and the consequent drop in pressure to atmospheric pressure upon the collapse of a generator tube prevents the formation of an explosive condition.

## CONVERTERS (Heat Consumers)

There is currently a wide variety of heat consumers available for HTW and experience is aiding the development of many more. HTW was originally regarded as a potentially dangerous heating medium. As such, it was seldom installed in occupied areas (offices, dormitories, etc.). Another factor which limited the direct application of HTW was its high heat storage capacity, causing a high degree of temperature override. The term converter covers a wide range of heat consumers. In general, HTW is converted to steam, domestic hot water, hot water heating, and warm air. The HTW flows through a tube arrangement and the medium to be heated passes over, around and in between the tubes. At no time does the HTW and the medium to be heated come into direct contact with one another.

## Air Heating Coils

Air heating coils are often referred to as warm air exchangers and are installed in a duct or plenum chamber along with a fan or blower. Air filters are normally installed between the blower and the return air from the building being heated or use a percentage (up to 100 percent) of fresh (outside) air. When fresh air is used, precautions must be taken to prevent freezing of the coil during winter operations. This can be accomplished in one of the following manners: (1) installation of a freezestat which closes the outside air damper or shuts off the fan; or (2) setting the HTW control valve to a minimum closed position. In most systems, the blower operates continuously and the HTW circulating through the coils is regulated by a temperature control valve or a motorized valve. The sensing bulb of the temperature control valve is installed in the heating duct on the downstream side of the heating coil. The motorized valve is actuated by a remote bulb thermostat. The sensing bulb of the thermostat is installed in the same location as the temperature control valve sensing bulb. The heating coils may be constructed of red brass, provided the HTW is maintained below 400°F. For temperatures of 400°F and above, cupronickel or steel should be used. Figure 64 illustrates a typical HTW air heating coil. The HTW is circulated around the coils. The control valve is mounted on the HTW return side of the coil to permit the valve to control a relatively cooler liquid than the HTW supply. (Most HTW systems are designed for a 150°F temperature drop between the HTW supply and return.) Temperature and pressure gauges are installed on both the supply and return sides of the HTW coil to determine the load drawn by the heat consumer. Air heating coils are normally installed in specially designed mechanical or utility rooms.

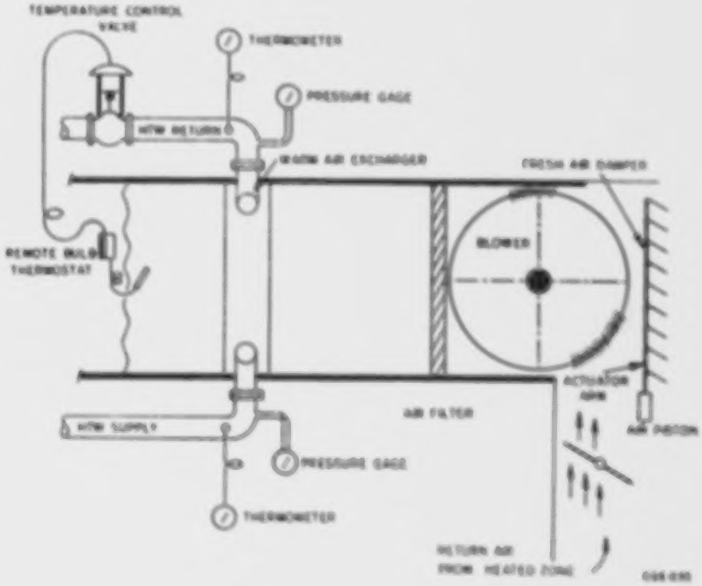


Figure 64. Air Heating Coil

## Space Heating Equipment

Convectors and radiant panel surfaces can be used for HTW use, however, the Air Force normally uses HTW unit heaters to heat industrial areas (supply warehouses, hangars, shops, etc.). The same material specifications pertain to unit heaters as applied to the air heating coils described on the previous page. Unit heaters normally have the HTW circulating through them continuously and the blower or fan is operated by either an outdoor thermostat or a room thermostat located in the occupied zone. Freezestats should be installed to secure fans or blowers when the HTW falls below a preset safe temperature to keep the coil from freezing. The most commonly used unit heater for HTW systems is the circular, vertical discharge type.

## OPERATION OF HTW SYSTEMS

The operation of any HTW system depends upon qualified personnel. However, guidelines are always provided to insure that all personnel inspect and operate equipment in the same manner.

### Preoperational Inspection

Before starting up a generator, inspect the installation carefully and make certain the following requirements are satisfied.

1. All installation, repair, and cleanup work completed.

2. All air and flue gas ducts and passages are tight and free from obstructions, and air and flue gas control dampers in good operating conditions.

3. Check all piping for leaks.

4. Inspect water column blowdown lines and gauge glasses for proper installation and connection on converted steam generators. Gauge glasses should be clearly visible from the operating floor and lamps, if provided, ready for operation. The drain valves on the water column must be closed and the valves between the column and generator locked open.

5. Check all auxiliary equipment such as fuel-burning, draft, ash disposal, feedwater and combustion control systems for proper installation and operational readiness. Make certain safety valve gauge has been removed and valves properly set and workable.

6. Make sure all generator manhole and handhole covers have been reinstalled. Check to make certain no one is inside, then see that access and observation doors are closed.

7. Make certain a hydrostatic test of the generator has been completed and approved by an authorized person.

NOTE: These preparations must be made before the inspector arrives on the base.

a. Provide a hand pump for the hydrostatic pressure test if the feed pump will not deliver one and one-half times the pressure at which any safety valve is set.

b. Make sure that Fire Surfaces are reasonably clean. Use a tube brush to remove soot from the tubes, and a wire brush to remove soot from the tube sheets and firebox. If the installation burns coal, remove the grate bars and clean the firebox plates along the grate line until the bare metal is exposed. Take care not to damage metal with sharp tools.

c. Provide gage to prevent safety valves from lifting when hydrostatic pressure is applied. If hydrostatic pressure tests on more than one generator are contemplated, provide sufficient gage for all safety valves of the boilers to be tested.

d. Permit generators taken off line for inspection purposes (including firebox and settings) to cool before they are drained. Immediately after draining, wash them thoroughly on the inside to prevent sludge deposits on internal surfaces, and remove all suspended solids, sediment, and loose scale.

e. Fill generators scheduled for hydrostatic pressure test with water at a temperature between 70° and 100°F; apply a preliminary pressure of 15 to 20 pounds less than working pressure, to insure that all test equipment is in proper working condition.

f. If the generator to be tested is on a common header with a second and the latter is to be kept in operation throughout the test, equip the pipe between the two with two valves and a drain or a blind joint.

g. Have available a supply of gaskets for manholes and handholes, and suitable wrenches for removing manhole and handhole covers.

h. Replace damaged and improper fusible plugs.

i. If insulation conceals manufacturer's inscribed data, remove the lagging and clean the surface carefully so that die-cut letters and figures can be read easily.

j. Assign a qualified plant operator to assist the inspector throughout the tests.

k. If controls are not designed for a pressure equal to the pressure of the proposed tests, remove them and plug the openings, unless cutoff valves are present.

8. The HTW generators and systems are boiled out to remove grease, oil, dirt, and protective coating from generator heating surfaces. This is generally used to clean newly erected generators, and systems or units which have been extensively repaired or retubed. If extensive repairs have been made on refractory setting or furnace, a drying-out will also be required to prevent damage to the brickwork.

9. Readiness of nitrogen supply and equipment, if the system is pressurized with inert gas.

## Starting and Operating HTW Systems

Operation of the HTW system includes starting up the system, adding additional units when required, initial filling of the system, rotating the pump in service and shutting down the system. Some guidelines are provided below.

### Starting up the Steam-Cushioned Combined Pumping System

When the system is cold and not under pressure, proceed as follows:

1. See that proper water level is carried in the expansion drum.

2. Open inlet and outlet valves in the HTW generator expansion drum and system.

3. Open inlet valve to circulating water pump. Start the pump and then slowly open the discharge valve.

4. Check waterflow through unit and vent air from headers and high points in the system.

5. Make final check of limit and safety controls and start the unit.

6. Light off the generator as follows:

a. Shut the dampers of the induced fan; close flue gas control sampling lines. Start induced draft fan.

b. Shut the dampers of the forced draft fan or other air control dampers, then start the forced draft fan.

c. If a regenerative air preheater is installed, start the rotor.

d. Purge the setting of all combustible gas by circulating air for at least 5 minutes at the rate of about one-fourth of the requirements for maximum capacity of the unit.

e. Light off the generator and keep a firing rate sufficient to raise the generator water from room temperature to the boiling point (212°F) in about 90 minutes. If the unit is filled with hot water, the time can be reduced, but it should not be less than 45 minutes. From this point on, increase the temperature of the water at the rate of 100°F per hour. In new boiler installations, check to see if expansion has caused any binding or interference.

f. Insure that combustion is complete, for incomplete combustion may occur with a cold generator and can be dangerous.

g. Slowly heat up system water and generator refractory. Control manually until operating pressure is reached, then switch to automatic if desired.

h. If expansion caused by heating up the system raises the water level in the expansion drum to near the highest permissible water level, blow down the boiler as required.

## Placing Additional Units in Service; Combined Pumping System in Operation

When a cold generator is to be placed in service with other units already in operation, proceed as follows:

1. Gradually open the bypass valve on the HTW generator inlet valve. When pressure on the unit equals the system pressure, open the inlet valve.

2. Gradually open the bypass valve on the HTW generator outlet valve. Allow the cold water in the unit to be circulated to the expansion tank.

3. When the temperature of the water entering the generator equals the temperature of the water leaving the generator, open the generator outlet valve and establish full circulation.

4. Light off the generator as instructed above and maintain a low fire until refractory is fully heated.

5. Set controls on automatic for normal operation.

## Starting Up a Steam-Cushioned Separate Pumping System

When a separate pumping station is heated, the water flowing through the system should not exceed the water flowing through the generator. All water returned from the system should be circulated through the expansion drum. When the system water temperature reaches 200°F, the water should be circulated only through the boiler, not through the system. This procedure raises the pressure in the expansion drum to the normal operation conditions, with a minimum firing rate. When operation pressure is reached, start circulating the water, through the system at 25 percent of the normal rate. As the return water temperature drops, increase the firing rate to maintain pressure in the expansion drum. Continue this procedure, increasing flow rate through the system as the return temperature continues to rise, until normal operating conditions are obtained. At this time the generator control system should be switched from manual to automatic. Throughout the operation, vent air from headers and high points in the system.

## Procedures for Starting Circulating Pumps

NOTE: Always start circulating cooling water through pump cooler before starting up the circulating pump.

1. Starting pump.
    a. Open pump suction valve.
    b. Start pump motor.
    c. Slowly open discharge valve.
2. Stopping pump.
    a. Close pump discharge valve.
    b. Stop pump motor.

NOTE: Continue to circulate cooling water for about 30 minutes (if system is pressurized).

c. When pump body is cold, close valve on suction side (if system is pressurized).

### Placing Additional Units in Service; Separate Pumping System in Operation

This operation requires some care since the requirements of the system have to be satisfied at the same time as those of the generator and they are conflicting in certain respects.

1. Cut in additional units when generators in use are operating at 75 percent of capacity. Do not wait until they are operating at full capacity.

2. The standby unit should be kept hot by a slight circulation through it. The bypass of the inlet valve serves this purpose. Proceed as follows:

-- Open the drum inlet valve and generator shutoff valves of the particular unit. Keep glove valves on generator inlet closed. Open bypass just sufficient to establish a slight circulation.

3. When the standby unit is to be placed in service proceed as follows:

a. Start generator circulating pump as previously described. Open globe valves on generator inlet and adjust flow rate through boiler to about 475 gpm.

b. Light off and maintain firing rate at about 20 percent of full capacity for about 30 minutes, then bring up firing rate gradually until generator outlet temperature matches that on other units. Put unit on automatic combustion control and slowly open the generator inlet valve until flow rate through all units is equal.

### Securing of Generator While One or More Units Remain in Service

As soon as fire is secured, reduce flow through generator to not more than 200 gpm and maintain until water temperature at outlet and inlet are practically the same.

1. Secure the generator circulating pump.

2. If generator is to be used as standby, maintain temperature by slightly opening the bypass valve. If unit is to be kept out of service for extended period, it should be cooled down. Close the expansion drum inlet valve on the generator outlet, close inlet on manifold, but leave inlet bypass valve open so that the unit remains under pressure.

3. The circulation is now interrupted so that the unit can cool down. Upon cooling down, the volume of the water will shrink and be replaced by water entering from the system.

4. While out of service, the unit should preferably be maintained under pressure or if this is not desirable then the inlet bypass valve may be closed and the unit isolated only when it is quite cold. Under no circumstances will the vent valve be opened.

### Shutting Down the Heating System

The final thing to consider when discussing system operation is removing the system from operation. To do this, proceed as follows:

1. Fill the expansion drum to high water level mark.

2. Maintain circulation in the heating system until the water contained in the districts has cooled down. Then proceed as follows:

a. Fully open mixing valves and close return valves. Water in the districts will now circulate without heat being added to it.

b. Secure fire on generators but maintain circulation for about one hour. Then stop the generator circulating pumps.

c. Close inlet valves on the generator manifold, but open bypass valves. Leave other valves open.

d. When water in the districts has cooled down below 200 degrees, secure district circulating pumps. Close motorized valves, crack open bypass on return valves and ke districts under pressure from the expansion drum. If the water level in the expansion drum drops below the low water mark, start makeup pumps and bring up water level.

e. When pressure in the expansion drum drops below 100 psig, close the bypass valves and isolate districts completely.

## BOILER INSPECTIONS

Before boilers are inspected, clean fireside, waterside, insure refractory and pressure part repairs have been completed.

### Inspections Standards

Qualified boiler inspectors will inspect boilers, accessories, and piping to determine the condition of the boilers and safety devices and to determine that boilers and safety devices are suitable for safe operation. Inspections will conform to the procedures set forth in the latest edition of the National Board Inspection Code published by the National Board of Boiler and Pressure Vessel Inspectors, Columbus, Ohio (Cost $1.00).

NOTE: When the Unite States has sole jurisdiction over leased facilities, these instructions supersede any existing state or municipal codes governing boiler furnace inspection.

### What Equipment Will be Inspected

MANDATORY INSPECTION. Steam boilers operating above 15 psi and high temperature hot water heating boilers operating above 160 psig will be inspected as prescribed by this section. Inspection of high temperature hot water boilers (not domestic water heaters) includes inspection of the expansion drum as well as the water tubes, headers, furnac and safety devices.

### Obtaining Inspection Service

1. The Defense Supply Agency, Defense Contract Services District, administers contracts each year for the service of a qualified company to provide boiler inspections at all Air Force bases within the Continental United States (excluding Alaska and Hawaii). For many years, the Hartford Steam Boiler Inspection and Insurance Company, Hartford, Connecticut, has provided this service.

2. Special inspections (outside the scope of the contract required by these instructions are considered necessary by major commands or base civil engineers) may be arranged through the Defense Supply Agency, defense contract Administration Services District, Cincinnati, Ohio.

3. If the company under contract to furnish boiler inspection service cannot make a special or emergency inspection, the base civil engineer may hire a recognized insurance company or a boiler inspection agency that specializes in such work. (An installation employee may not make such special inspections.)

4. The contract will provide the following five types of inspections when they are included in the annual schedule submitted by the major command.

    a. Type "A"--Internal and external inspection.

    b. Type "B"--Internal and external inspection, followed or preceded by external inspection while boiler is under hydrostatic test.

    c. Type "C"--External inspection while under steam pressure or filled with water. (Boiler will be under pressure for this inspection.)

    d. Type "D"--External inspection while under hydrostatic test.

    e. Type "E"--Internal and external inspection of expansion tanks used with high temperature water boilers.

5. Overseas and other off-continent commands are authorized to employ qualified and competent boiler inspectors to perform the inspections. These inspectors will not be supervised by personnel at base level. They will prepare AF Form 1222, "Boiler Inspection Report," on each boiler inspected and submit it to the Director of Civil Engineering of the appropriate major command. Detailed comments on these reports will be made by an attached memorandum.

The boiler inspector will make the types of inspections requested in the annual schedule submitted by the major command to the Defense Supply Agency, Defense Contract Administration Services District, Cincinnati. If an inspector determines that an additional inspection is necessary, the base civil engineer will authorize him to perform it before he leaves the base. However, such additional inspection will not constitute authority to delete subsequent scheduled inspections. The following inspections are required as a minimum.

1. Steam boilers assembled on the site require a type "B" inspection before they are placed in initial operation.

2. Steam boilers assembled at place of manufacture and stamped with approval of a qualified inspection agency (such as the Hartford Steam Boiler Inspection and Insurance Company): A type "B" inspection, after manufacture and before being placed in initial operation.

3. All Steam Boilers: Twice annually a type "A" inspection first and approximately six months later, a type "C" inspection.

4. Steam boilers in questionable condition, used boilers reinstalled, boilers which have had major repairs, recommended by the boiler inspector or required by the base civil engineer: a type "B" inspection before being placed in service.

5. New HTW (High Temperature Water) boiler installation: a type "B" inspection before operation.

6. Other HTW boilers: a type "A" inspection annually.

7. Expansion tanks: a type "E" inspection annually.

Boilers out of operation indefinitely need not be inspected by inspection agency. However, they should be inspected annually by base civil engineer personnel to evaluate visible deterioration and renew protection against corrosion, if necessary. Also, a boiler that has missed an inspection period must be given the appropriate inspection before it is placed in operation again.

The hydrostatic pressure used during a type "B" or type "D" inspection will be one and one-half times the pressure setting of the safety valves. If safety valve setting has been lowered, it will not be raised without approval of the boiler inspector. Boiler inspectors will insure that the boiler, accessories, and adjacent piping are in condition to be operated at pressure up to the safety valve setting.

Before leaving the base, the inspector will orally report any serious defects to the base civil engineer (or his representative). Boilers found to be in dangerous condition will not be operated until repaired.

A hydrostatic test is a water pressure test to prove the strength and tightness of a boiler.

After repairs are made, a hydrostatic test is performed on the boiler to check for leaks around rolled and beaded areas. Should any leaks be found, reroll tube or tubes that are leaking making sure not to overroll.

NOTE: Hydrostatic pressures are 1 1/2 times the safety valve setting. Hydrostatic test required, 1 every 3 years

The boiler is the principal and most costly unit in a central boiler plant. Preventive maintenance of the unit represent the difference between a normal useful life of fifty years or a short life with much time lost for repair and possible injury to operating personnel.

All boilers have general characteristics and need similar care. General care of the boilers follows two rules: stop leaks and keep the boiler clean. One of the boiler inspections required to determine its condition is the hydrostatic pressure test. This study guide will provide you pertinent information regarding this test under the following main topics:

NOTE: The preparations must be made before the boiler inspector arrives on the base.

1. Provide a hand pump for the hydrostatic pressure test if the boiler feed pump will not deliver one and one-half times the pressure at which any safety valve is set.
2. Make sure that Fire Surfaces of Boilers are reasonably clean. Use a tube brush to remove soot form tubes, and a wire brush to remove soot from the tube sheets and firebox. If the installation burns coal, remove the grate bars and clean the firebox plates along the grate line until the bare metal is exposed. Take care not to damage metal with sharp tools.
3. Provide gags to prevent pressure relief valves from lifting when hydrostatic pressure is applied. If hydrostatic pressure tests on more than one boiler are contemplated, provide sufficient gags for all safety valves of the boilers to be tested.
4. Permit boilers taken off line for inspection purposes (including firebox and settings) to cool before they are drained. Immediately after draining, wash them thoroughly on the inside to prevent sludge deposits on internal surfaces, and remove all suspended solids, sediment, and loose scale.
5. Fill boilers scheduled for hydrostatic pressure test with water at a temperature between 70° and 100°F; apply a preliminary pressure of 15 to 20 pounds less than working pressure, to insure that all test equipment is in proper working condition.
6. If the boiler to be tested is on a common header with a second boiler and the latter is to be kept in operation throughout the test, equip the steam pipe between the two boilers with two valves and a drain or a blind joint.
7. Have available a supply of gaskets for manholes and handholes, and suitable wrenches for removing manhole and handhole covers.
8. Replace damaged and improper fusible plugs.
9. If insulation conceals manufacturer's inscribed data, remove the lagging and clean the surface carefuly so that die-cut letters and figures can be read easily.
10. Assign a qualified boiler plant operator to assist the inspector through the test.
11. If boiler gauges and controls are not designed for a pressure equal to the pressure of the proposed tests, remove them and plug the opening, unless cutoff valves are present.

## LOGS

The operator prepares daily log forms locally and uses them for HTW central heating plants and systems. He will also assure that information from the daily forms is posted to AF Form 1165, Monthly High Temperature Water Plant Operating Log, and AF Form 1163, Monthly High Temperature Water Distribution System Operating Log.

These logs are prepared and distributed in the same manner as the Monthly Steam Boiler Plant Operating Log, which were discussed earlier.

## SUMMARY

You have studied specific facts about the basic design of HTW generators. You have learned how steam boilers could be connected and the types of specially designed generators. You have been given the range of the HTW systems as 320° and above. Thermal efficiency is higher because the heat storage capacity of water is 300 times the amount of heat per volume of air and 30 times greater than comparable steam systems. How systems are classified as to type of pressurization, pumping system, and generators or a combination of these.

The operation procedures and the monthly high temperature water plant operating log has been explained. The most important item to remember is safety in the operation of the system. Remember you must maintain circulation, while bringing the temperature up slowly, to avoid damage to personnel and equipment.

## QUESTIONS

1. What are the three types of special designed generators?
2. What are the problems when converting steam boilers?
3. In what type of system does the water and steam come in direct contact?
4. What is the special type of meter used in HTW plants?
5. What are the methods of system pressurization?
6. What are two types of pumping systems?
7. What are the types of heat-consuming equipment used in an HTW system?
8. How many expansion drums can be used on a system?
9. What type of inert gas is used for pressurization?
10. Water will be raised from room temperature to 212°F in how many minutes?

WORKBOOKS
J3ABR54532 001-VI-1 thru VI-3

Technical Training

# Heating Systems Specialist

# CENTRAL PLANT AND HIGH TEMPERATURE WATER HEATING SYSTEMS

July 1983

3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

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This publication supersedes WBs J3ABR54730-IV-1 thru IV-5, dated March 1981

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

WB J3ABR54532 001-VI-1
July 1983

## Theory of Operation and Construction of Steam Heating Systems

OBJECTIVES

Given information, identify principles concerning theory of operation and construction features of steam heating systems with 70% accuracy.

Given information, identify the procedures for removing and installing boilers with 70% accuracy.

Given information, identify basic facts about components of feedwater system with 70% accuracy.

Given information, determine procedures for installation, operation and maintenance of reciprocating pumps by answering four out of five questions correctly.

Given information, determine step-by-step procedures for operating and servicing pressure/temperature recording equipment with 70% accuracy.

Given information, operate and service draft indicating and regulating equipment with instructor assistance.

Given information, perform service of flow meters and recorders with instructor assistance.

Given information, troubleshoot boiler flame control system with instructor assistance.

PROCEDURES

### EXERCISE 1

### Construction Features

NOTE: Complete the following statements. Use the study guide as a reference.

1. The two main types of boilers are

   a. ______________________________.

   b. ______________________________.

2. Boiler steam drums provide four functions. Name them.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

3. Water-tube boilers may be classified as ______________________________

   ______________________________

4. Straight-tube boilers can be classified as ____________________

____________________.

5. Walls or partitions used to direct gases of combustion are called ____________________

____________________.

6. Furnace enclosures (setting) may be of four types. Name them.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

7. Name the pressure parts of a boiler.

____________________

____________________

____________________

8. Flat boiler surfaces are held in place by ____________________.

Name five types: ____________________

____________________

____________________

____________________

____________________

9. What are steam baffles used for? ____________________

____________________

10. List the size of boiler tubes. ____________________

____________________

11. List the size of boiler flues. ____________________

____________________

12. List the types of fire-tube boilers.

a. ____________________

b. ____________________

c. ____________________

13. How are boiler tubes installed in both fire-tube and water-tube boilers?

14. Explain what the ASME is and why the Air Force needs to follow the ASME code.

## EXERCISE 2

## Installing a Boiler

NOTE: Complete the following statement. Use the study guide as a reference.

Explain the procedures for installing a boiler.

## EXERCISE 3

NOTE: Identify the parts with the proper number.

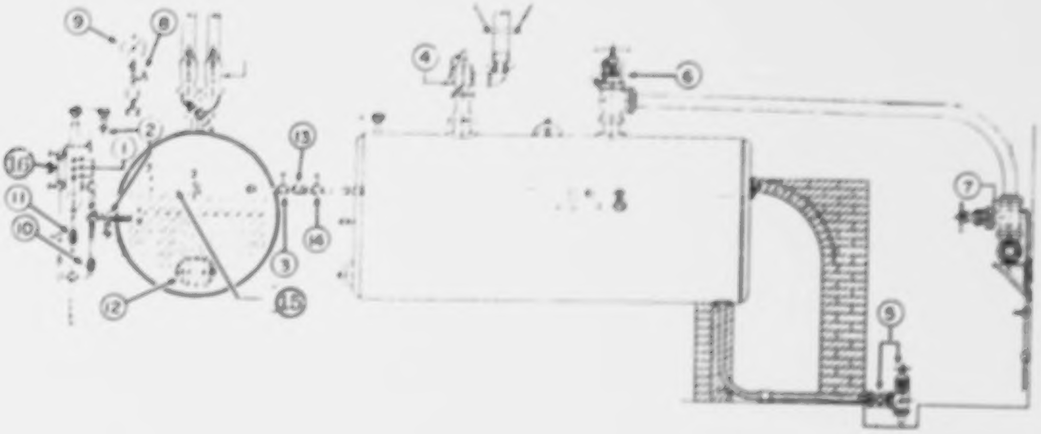

Figure 1. Boiler Components

Safety Valve ________________

Try-Cocks ________________

Manhole ________________

Feedwater Line Gate Valve ________________

Water Column Blowdown Valve ________________

Gauge ________________

Nonreturn Valve ________________

Blown Down Valves ________________

Steam Stop Valve ________________

Feedwater Line Globe Valve ________________

Pressure Gauge Test Connection ________________

Feedwater Line Check Valve ________________

Gauge Glass ________________

Water Column Isolation Valves ________________

## EXERCISE 4

## THEORY AND CONSTRUCTION OF RECIPROCATING PUMPS

NOTE: Use Study Guide as reference.

1. What is a reciprocating pump?

2. What is a reciprocating pump used for?

3. What is the lost motion used for?

4. List the major components of a reciprocating pump

5. Explain "lost motion".

## EXERCISE 5

## STEAM TURBINES

NOTE: Use Study Guide as reference.

1. What is a turbine?

2. List five main components of a steam turbine.

    a.

    b.

    c.

    d.

    e.

3. How are steam turbines classified?

    a.

    b.

    c.

    d.

    e.

4. Low pressure turbines operate at pressures of ______________________________.

5. Medium pressure turbines operate at pressures of ______________________________.

6. High pressure turbines operate at pressures of ______________________________.

7. A gas turbine converts the chemical energy of a fuel into mechanical energy through ______________ ______________.

8. Hot gases enter the turbine at about ________ to ________ temperature Fahrenheit.

9. Hot gases exhaust from the turbine at about ________ temperature Fahrenheit.

10. What is the main difference between steam and gas turbines?

11. What does the cylinder contain?

12. What does the rotor contain?

## EXERCISE 6

## INSTALLATION, MAINTENANCE AND OPERATION OF RECIPROCATING PUMP

NOTE: Use Study Guide as reference.

1. How many times per cycle does a single-acting reciprocating pump discharge water?

2. How often are reciprocating pumps cleaned and repaired?

3. How is the output of a reciprocating pump controlled?

4. Where do you find the guidelines for installing the reciprocating pump?

5. What safety precaution should be followed when working with reciprocating pumps?

## EXERCISE 7

## OPERATING AND SERVICING OF PRESSURE/TEMPERATURE RECORDING EQUIPMENT

NOTE: Use Study Guide as reference.

1. The purpose of pressure control is what?

2 Two types of pressure controls are?

3. What is the purpose of the air flow switch?

4. What is the purpose of burner interlock controls?

5. The firing rate control assures what?

6. The primary element used in pressure/temperature recording equipment is?

7. Draft gauges can be of two types, name them.

8. Indicating-type pressure gauges are graduated to read never less than what?

9. What type pressure control has no differential setting?

10. The two methods for calibrating indicating type pressure gauges are?

## EXERCISE 8

## OPERATE AND SERVICE DRAFT INDICATING AND REGULATING EQUIPMENT

PROCEDURES

CAUTION: Remove all jewelry.

1. Check for clean glass.
2. Check for proper lighting.
3. Check for proper mounting.
4. Check for proper operation.

## EXERCISE 9

## SERVICE OF FLOW METERS AND RECORDERS

PROCEDURES

CAUTION: Remove all jewelry.

1. Using lever pull ink pins away from chart.
2. Remove and replace chart.
3. Reposition ink pins.
4. Check for leaks.
5. Check for loose connections.
6. Check for dirt or foreign matter.
7. Check for binding of moving parts.

## EXERCISE 10

## BOILER FLAME SAFEGUARD

PROCEDURES

CAUTION: Remove all jewelry

1. Remove programmer.
2. Place programmer in tester.
3. Check operation.
4. Remove programmer from tester.
5. Replace programmer.

## EXERCISE 11

## BOILER FLAME CONTROL SYSTEM

NOTE: Use Study Guide as reference.

1. What is the purpose of the boielr flame control system?

2. How quickly will the control system shut off all fuel valves upon loss of flame signal?

3. The scanner can be located how far from the control?

4. Why must the scanner wire be run through its own junction box and conduit?

5. What is used to clean the contacts of the programmer?

6. If programmer is shut down for an extended period of time, the power should be turned on when?

7. If spare programmers are available they should be rotated how often?

8. How often is a flame failure check made?

9. How often is a flame current check made?

10. What is the purpose of the flame current check?

11. What is the purpose of the flame failure check?

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

WB J3ABR54532 002-VI-2
July 1983

# Boiler Operations

## OBJECTIVES

Given information, operate a steam boiler with instructor assistance.

Given information, determine step-by-step procedures for operating and maintaining oil preheaters with 70% accuracy.

Given simulated job entries, complete steam logs and fuel consumption report with instructor assistance.

## PROCEDURE

### EXERCISE 1

Using a feedwater regulator, adjust and maintain the proper water level.

CAUTION: Remove all jewelry.

1. Proceed to boiler area with instructor.
2. Trace feedwater system and explain the operation of each piece of equipment.
3. Check water level.
4. Insure float is free moving.

   NOTE: Blowdown feedwater control.

### EXERCISE 2

Operate high or low pressure boiler.

CAUTION: Remove all jewelry.

1. Make preoperational inspection.

   NOTE: Report all discrepancies to the instructor.

2. To start a cold boiler and system, proceed as follows:
   - a. Open air vent (cock)
   - b. Check water level
   - c. Prove water level
   - d. Check all fittings
   - e. Line up feedwater system

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f. Line up fuel system

g. Check all air dampers

h. Line up electrical system

i. Operate feedwater pump

j. Light off boiler

k. Check flame control

l. Check airflow control

m. Check water level control

n. Close air vent after steam is formed

o. Check boiler and fittings for steam or water leaks

p. Secure the boiler and systems

3. Have the instructor check your work.

## EXERCISE 3

## BOILER OPERATIONS

NOTE: Use Study Guide as reference.

1. What must be done before operating any boiler?

2. What valves must be closed?

3. What valves must be locked open?

4. What must be done to the safety valve?

5. What must be done to the cock in the pressure gauge line?

6. On auxiliary equipment having bearings, what must be checked?

7. What is used for safety against high intensity sound?

8. What is the temperature of the water used to fill the boiler?

9. The temperature difference between the water and pressure parts should be?

10. What is the reason for not having a big temperature difference?

11. Using a balanced draft system which draft fan is started first?

12. How long is the boiler purged for?

13. What rate is the purge done at?

14. How long should it take to raise the water temperature from room temperature to the boiling point (212°F)?

15. How much temperature increase per hour above 212°F?

16. You close the drum vent valve at what pressure?

17. What is the purpose of having the drum vent valve open?

18. What is normal water level during boiler start up?

19. Boiler operators have three main responsibilities, what are they?

20. What does a boiler operator do if he finds an unsafe condition?

21. How often is the water column blown down?

22. How often is the gauge glass blown down?

23. Before securing the boiler, what should be operated?

24. How do you reduce the output of the boiler?

25. How long is the draft equipment operated during shut down period?

26. How fast should the boiler be cooled down?

27. What could happen, if the boiler is cooled off too quickly?

28. At what pressure is the steam drum vent valve opened?

## EXERCISE 4

NOTE: Use Study Guide as reference.

1. What is a preheater used for?

2. What types of fuel require preheating?

3. The first heating of the fuel oil is done where?

4. What is the purpose of heating the fuel oil in the fuel oil storage?

5. The temperature of the fuel oil during the first preheating stage in the storage tank is at what temperature?

6. The second preheating is done where?

7. What temperature is obtained during the second preheating stage?

8. List the three types of preheaters.

9. What is used to protect the steam preheater from excessive pressure?

10. When is it desirable to use an electric preheater?

11. The below-the-water-line heaters use what as a heating medium?

## EXERCISE 5

## EMERGENCY BOILER SHUTDOWN

NOTE: Use STudy Guide as reference.

1. What is the most common boiler emergency?

2. If there is no water showing in the gauge glass, what action should be taken?

3. What is done to the steam stop valve, if a furnace explosion occurs?

4. What is done if you have failure of combustion control?

5. How long is the boiler purged when you have complete failure of ignition?

6. How do you maintain normal water level if a failure of the feed water regulator occurs?

7. What is done if the induced draft fan fails?

8. What is done if the forced draft fan fails?

## EXERCISE 6

## OPERATING LOGS

1. Complete the following statement/questions concerning the operation logs.
   a. How often is AF Form 1458 prepared?
   b. How often are entries made on AF Form 1458?
   c. How often are entries made on AF Form 1404?
   d. When is AF Form 1404 submitted to major air command?

2. Complete entries given by instructor.

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

WB J3ABR54532 002-VI-3
July 1983

# High Temperature Water Heating Systems

## OBJECTIVES

Given information, identify the methods of producing high temperature water with 70% accuracy.

Following step-by-step procedures, operate and maintain the high temperature hot water heating system trainer and distribution system with instructor assistance.

## PROCEDURE

### EXERCISE 1

### High Temperature Water Plants

Using information, maintain a pumping system with instructor assistance.

NOTE: Complete the following statements using the study guide as a reference.

1. The minimum temperature differential allowed between boiler inlet and outlet is

______________________________.

2. Name the major components that are eliminated from HTW systems that are normally required for steam.

______________________________

______________________________

______________________________

3. The three basic methods of generating HTW are

a. ______________________________

b. ______________________________

c. ______________________________.

4. The three types of forced circulation generators are

a. ______________________________

b. ______________________________

c. ______________________________.

5. Name the type of HTW system which brings steam and hot water in direct contact.

______________________________

6. List the problems that may be encountered when converting existing boilers.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

7. Expansion drums are used to ______________________________

______________________________.

8. The three methods of pressurizing HTW systems are

a. ______________________________

b. ______________________________

c. ______________________________.

9. Why are HTW systems pressurized?

______________________________

______________________________

10. Nitrogen is an example of a/an ______________ gas.

11. The primary purpose for using pumps in a HTW heating system is

______________________________

______________________________.

12. Name the two principal pumping systems.

a. ______________________________

b. ______________________________

13. Name the type of pumping system which uses a separate pump for boiler circulation only.

______________________________

14. In the combined pumping system, the pump is used to circulate water through the system and ______________________________.

15. The bypass connection is used in all HTW combined pumping systems and is actuated by ______________________________.

16. The control that is activated by a minimum flow through the generator is the

______________________________________________.

17. The control which is activated due to abnormal water levels in the expansion drum is the ______________________________________________.

18. A BTU meter can indicate and record three things. They are

a. ______________________________________________

b. ______________________________________________

c. ______________________________________________.

19. What is AF Form 1165? ______________________________________________

______________________________________________

20. What is AF Form 1163? ______________________________________________

______________________________________________

21. What is used for the daily log in HTW plants? ______________________________

______________________________________________

Checked by ______________________
Instructor

## EXERCISE 2

### Operation and Maintenance of Plants and Systems

### Preoperational Inspection

_____ All installation, repair and cleanup work completed, including cleaning and flushing of heat carrier pipes

_____ All conduits and passages tight and free from obstructions

_____ All insulation properly applied and dry

_____ All auxiliary equipment required for operation; i.e., strainers, drains, vents, provision for pipe expansion, etc., properly installed and ready for service

### Operation of the HTW generator

1. HTW Generator Start-Up

   a. Line up the electrical system.

      (1) Insure main switches on the Master Panel for circulating pumps, makeup pump and boiler power are in the OFF position

(2) Place Master Panel circuit breaker ON

(3) Place Master override switch ON

b. Insure proper water level in the expansion drum.

(1) Maintains a 75 - 78% full drum

(2) Open makeup pump supply and discharge valves

(3) Turn ON electrical power to pump

NOTE: When the expansion drum water level is low, the makeup pump will operate until the water level is attained.

If the water level is too high, blow down the system through the generator or expansion drum until the proper level is attained.

WARNING: This is the only time you may blow down the system through the generator.

(4) Insure the expansion drum vent is open

c. Check both the system pump and the generator pump.

(1) Insure the lubricating oil level is correct

(2) Open the cooling circuit valves until a slow, steady stream is flowing into the drains

d. Line-up the HTW system -- supply lines are dark blue, return lines are light blue

(1) Trace the supply line from the generator to the expansion drum, from the expansion drum through the system pump and out to the distribution system.

(2) Trace the return line from the distribution system back through the generator pump to the generator.

e. Line-up the load bank.

(1) Open the supply and return line valves to the load bank

(2) Turn on the four load bank switches (Master Panel)

f. Start the circulating pumps by

(1) Opening pump inlet (both generator and system pump).

(2) Starting pumps.

(3) Slowly opening discharge valves.

g. Start burner equipment by

(1) Opening the main gas valve to burner.

(2) Opening the manual gas valve for pilot.

(3) Lining up gas or oil valves as directed by instructor.

(4) Setting the fuel selector switch to GAS or OIL as instructor directs

(5) Turning on the main power switch to burner control

(6) Setting the firing selector switch to LOW FIRE POSITION

NOTE: The burner will fire automatically; if burner fails, consult the troubleshooting section of the maintenance manual.

(7) Allowing burner to fire on LOW FIRE to ensure proper temperature rise

2. Operational Checks of Generator and System

a. Bleed air from all high points of the HTW distribution system.

b. Maintain proper water level in expansion drum (refer to step 1b).

CAUTION: Due to heat expansion of water, the water level in the expansion drum will rise.

(1) Use expansion drum blowdown if water level is high.

(2) If water level in drum drops below the preset minimum, the firing equipment will automatically be secured until the make-up pump raises the water to the proper level.

c. Maintain pressure on the system by

(1) Closing the expansion drum vent SLOWLY when you have a steady stream of vapor flowing from the drum.

CAUTION: If the vent is closed quickly, the water will surge in the expansion drum.

(2) Maintaining proper water level in the expansion drum.

NOTE: Operate the generator until the preset temperature is obtained -- 320°F water and 120 psi steam pressure.

d. Perform operational checks and record

(1) Temperature (supply) ____________________

(2) Temperature (Return) ____________________

(3) Supply pump discharge pressure ____________________

(4) Return pump discharge pressure ____________________

(5) Distribution flow ____________________

(6) Return flow ____________________

(7) Expansion drum

(a) Temperature ____________________

(b) Pressure ____________________

(8) Stack temperature ____________________

e. Inspect circulation pump for the following.

    (1) Abnormal vibration and noise

    (2) Abnormal pressure and flow conditions

    (3) Leaking packing

    (4) Hot bearings

    (5) Hot stuffing box

    (6) Temperture of gland cooling water

f. Inspect valves for the following.

    (1) Leaks

    (2) Damage to insulation

    (3) Bent stems

## 3. System Shutdown

Shutdown the system by

a. Securing generator burning equipment by securing electrical power and securing gas lines or oil lines.

b. Securing circulating pumps by closing discharge, securing electrical power and closing pump supply.

CAUTION: Circulating pumps CANNOT be shut down until the temperature is BELOW 200°F.

c. Securing cooling water to circulating pumps.

d. Securing make-up pump.

e. Securing ALL electrical switches.

## EXERCISE 3

## PROCEDURES FOR HYDROSTATIC TEST ON HTW

NOTE: Answer following questions.

1. What is the purpose of a hydrostatic test on the generator?

2. How much pressure is used on the generator to perform the hydrostatic test?

3. What must be done to the pressure relief valve on the generator?

4. What type of inspection is done on the generator?

5. How often is the hdyrostatic test done?

STUDY GUIDES
J3ABR54532 001-VII-1 thru -4

Technical Training

# Heating Systems Specialist

# BOILER MAINTENANCE AND STEAM DISTRIBUTION SYSTEMS

September 1983

3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

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## EXPLANATION OF TERMS

ABNORMAL--Not normal.

ACCESS--Permission or ability to enter.

ACCUMULATIONS--Collections.

ADHERING--Sticking.

ADJOINING--Next to, beside.

ADJUST--Regulate.

ADJUSTMENT--To regulate.

AFFECTING--To influence.

ALIGNMENT--Putting into precise position.

ALLOY--Mixture of base metals.

ALTERNATING--Changing back and forth.

ANNUALLY--Once a year.

APPROACHES--Entries, getting closer.

APPROPRIATE--Right or correct.

APPROXIMATELY--About, almost, close.

ARRANGEMENT--Having been put in order.

ASBESTOS--A fire resistant material.

ASSEMBLED--Collected, put together.

ATMOSPHERE--Air.

AUTHORIZED--Officialy allowed.

AUTOMATIC--Self acting.

AUXILIARY EQUIPMENT--Extra equipment necessary.

AVAILABILITY--To have close to use.

BASICALLY--Fundamental.

BELLOWS--Expandable device used in traps, valves and controls.

BIMETALLIC--Composed of two different metals.

BLOWDOWN--Discharge, drain partially.

BLOWER--Fan.

BLOWING--Act of moving air.

BLOW OFF--Blowdown.

BODY--The main part.

BOILER--Enclosed vessel used to generate steam.

BRICKWORK--Work of or with brick.

BURNER--Part of boiler which produces flame.

BYPASS--To go around.

CALIBRATE/CALIBRATION--Find, change or mark of graduation.

CAM-ACTUATED--Operated or controlled by a cam.

CAPABLE--Able to.

CAPACITY--Measure of content, maximum output.

CAPILLARY--Small bore tube used to transmit pressure.

CASING--Body.

CASTABLE--Able to be molded.

CAULKED--Stopped up, sealed against leakage.

CENTRIFUGAL--Going to acting in a direction away from a center or axis.

CERTIFIED--Authorized by a certificate.

CHAMBER--Cavity or compartment.

CHARACTERISTICS--Traits, qualities or properties.

CIRCULATE--To move.

CIRCULATION--The movement of.

CIRCULATOR--That which causes to circulate.

CLASSIFIED--Divided into classes.

CLINKERS--Stony matter fused together.

COMBINATION--Two or more.

COMBUSTION--Burning.

COMMERCIAL--Used for or by business.

COMMUNICATION--Exchange or express thought, ideas, opinions or feelings.

COMPENSATE--Make up for.

COMPONENTS--Parts of.

COMPRESSION--Squeezing or compacting with power.

CONDENSATE/CONDENSE--Steam turned back into water.

CONDITIONS--Provisions or working status.

CONDUCTIVITY--Degree of ability to transmit electricity.

CONDUIT--Tube in which pipes or wires are run.

CONNECTED/CONNECTION--Attached to.

CONSISTENCY--Thickness.

CONSTANT--Always or lasting.

CONSTRUCTION--Made or made of.

CONSUMER/CONSUMING--User, using.

CONTACTS--Electrical touching points.

CONTINUOUS--Always or lasting.

CONTRACTION--Shrinkage.

CONTROL--Having power over.

CONVERTERS--Device used to change heating mediums (i.e., steam to water).

CORRESPONDING--To be equivalent or parallel.

CORROSION--Act of eating away by degrees.

CYCLE--A sequence of a recurring succession of events.

DAILY--Once a day.

DAMAGE--Destroy or destruction.

DAMPERS--A plate used for regulating the flow of air or gases.

DEAERATE/DEAERATING/DEAERATION--Removal of air from water.

DEAERATOR--Device used to deaerate with.

DECREASE--To lessen or make smaller.

DEFECTIVE--Not as it should be.

DEMAND--Requirement.

DEPOSITS--Collections of.

DESIGN--Plan or purpose.

DESIGNATED--Picked or chosen.

DIAGRAMS--Simplified drawings.

DIAMETER--A straight line through the center of a circle.

DIAPHRAGM--Thin membrane divider or partition.

DIFFERENCE--Sum of subtraction.

DILUTION--Act of reducing strength.

DIMENSIONS--Measurements of an object's shape.

DISCHARGE/DISCHARGED--Remove, throw out.

DISCUSS--Talk about.

DISMANTLE--Take apart.

DISSOLVE--To cause to disperse or pass into solution.

DISTRIBUTED/DISTRIBUTION--Convey, give out or supply portions of.

DOWNWARD--From a higher place to a lower.

ECONOMIZER--Closed feedwater heater using hot stack gases as a heating medium.

EFFICIENCY/EFFICIENT--Measurement of oepration or ability.

ELECTRICAL--Pertaining to electricity.

ELECTRONIC--Pertaining to electronics.

ELEMENT--A part or piece of.

EMERGENCY--Pressing need calling for immediate action.

EQUALIZE--To make equal.

EQUILIBRIUM--Balance.

EQUIPMENT--Implements used in an operation or activity.

ESTABLISHED--Instituted, recognized.

EVALUATE--To examine and judge.

EXCESSIVE--Going beyond a limit.

EXHAUST--Already used once.

EXPAND/EXPANDED/EXPANSION--Increase in size or volume.

EXPLOSIONS--Violent outbursts.

EXPOSED--Uncovered or unprotected.

EXTERNAL--Outside.

EXTREME--Maximum.

FACILITIES--Something built, installed or established to serve a purpose.

FAILURE--Falling short.

FEATURE--A special attraction.

FEEDWATER--All water put or to be put into a boiler.

FIREBOX--Chamber that contains a fire.

FIREBRICK--Used to build furnace refractories.

FITTINGS--Various controlling devices installed on a boiler.

FLASHING--Rapid conversion of hot water to steam due to a pressure drop.

FLEXIBLE--Bendable or pliable.

FLUCTUATION--Changing from a norm.

FORCED--Done or produced with effort.

FROST LINE--Depth to which the ground freezes.

FUNCTION/FUNCTIONING--Work, perform.

FURNACE--Where initial combustion and burning of fuel takes place.

FUSIBLE PLUG--Brass plug with tin core, used as a low water warning device.

GASES--Mixture of carbon and oxygen produced and given off in the burning process.

GASKET--A ring of material fitted tightly around a joint to keep it from leaking.

GENERATE/GENERATED--To make or produce.

GRADUATED--Marked with degrees of measurement.

GRAVITY--Force that draws objects toward the center of the earth.

HAND-HOLE--Hand sized orifice in a boiler to facilitate maintenance.

HARMFUL--Damaging, injurious.

HEADER--Pipe or tube shared by two or more boilers, objects or devices.

HEATING--The act of increasing the temperature.

HORIZONTAL--Parallel to the horizon.

HYDRAULIC--Operated, moved or effected by a liquid, i.e., water or oil.

HYDROSTATIC TEST--Filling boiler with water to a pressure one and one-half times the safety valve setting.

IGNITION--Act of setting on fire.

ILLUSTRATED/ILLUSTRATES--Drawn, pictured or shown.

IMPINGEMENT--Encroachment or infringement.

IMPORTANT--Having much meaning or value.

IMPRACTICAL--Not practical.

INADEQUATE--Not enough or not good enough.

INCHES--Units of measurement equaling 1/12 of a foot.

INCREMENTS--Units.

INCREASE--Add to.

INDEFINITELY--Unknown amount of time.

INDEPENDENT--Not depending on.

INDICATE/INDICATING--Point, direct or show.

INDUCED--Sucked up, brought on.

INDUSTRIAL--Relating to industry.

INFORMATION--Communication of knowledge.

INJECTOR--A unit to force water into a boiler.

INLET--Entry.

INSPECT/INSPECTION--To check or look carefully.

INSTALL/INSTALLED--To set up for use.

INSTALLATION--Air Force bases or properties which contain heating equipment.

INSTRUCTIONS--Procedures.

INSULATE/INSULATION--Protect or cover.

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INTELLIGENT--Able to understand.

INTEGRATE/INTEGRATED--Mix together.

INTERFERE--To hinder.

INTERMITTENT--Coming and going at intervals.

INTERNAL--Inside.

INVERTED--Upside down.

IRRESPECTIVE--Without regard.

ISOLATING VALVE--Valve used to separate a device from the main flow.

JURISDICTION--Control or authority over.

LAMINATIONS--Layers of bonded materials.

LATTER--Relating to the last or more recent.

LETHAL--Deadly.

LIMITATIONS--Limits.

LINKAGE--System of bars, rods or links.

LINTEL--Threshold.

LOCATED/LOCATION--Indicates place or site.

LONGITUDINAL--Placed or running lengthwise.

LUBRICATE/LUBRICATED/LUBRICATION--To make slippery, usually with grease or oil.

MAGNESIUM--A form or type of insulation.

MAINTAIN--To keep in existing state.

MAINTENANCE--To service or repair a piece of equipment.

MALFUNCTION--Failure to operate normally.

MANUAL/MANUALLY--Worked by hand.

MANUFACTURER--Maker.

MASONRY--To do with stone.

MAXIMUM--Most or highest limit.

MECHANICAL--Operated by a machine.

MECHANISM--Mechanical operation or action.

METER--Indicating type measuring device.

METHOD--Way of doing.

MINIMUM--Least or lowest limit.

MISALIGNMENT--Not aligned.

MIXTURE--State of being mixed.

MOISTURE--Wetness.

MONTHLY--Once a month.

MORTAR--Mixture of cement of lime with sand and water to hold bricks together.

MOVEMENT--Change of place, position or posture.

NECESSARY--Needed.

NIPPLE--Short piece of pipe.

NONCONDENSABLE--Unable to be condensed.

NON-RETURN VALVE--Valve permitting flow only in one direction.

* NORMAL--Average.

OBSERVATION--Watching.

* OBTAINED--Got or received.

OPERATE/OPERATING/OPERATION/OPERATIONAL--Relating to work.

OPERATOR--One who operates.

OPTIMUM--Best.

ORIFICE--Hole or opening.

OUTLET--Exit.

OXYGEN--A gas without color, taste or odor, and is a chemical element ($O_2$).

PACKAGE--Moderate sized unit with all essentials.

PASSAGE--Channel, course, tunnel or corridor.

PENETRATE--Pass into or through.

PERCENT--Reckoned on the basis of a whole divided equally into one hundred parts.

PERFORATIONS--Holes.

PERFORM--Do.

PERIODICALLY--Fixed intervals between set times.

PERMANENT--Fixed or lasting.

PERMISSIBLE--Allowed.

PERSONNEL--People of a unit or group.

PISTON--A sliding piece moved by a moving against a liquid or gas.

PLASTIC FIREBRICK--Unburned brick that can be shaped to form refractory linings.

PNEUMATIC--Operated by air.

POSITION--Place or posture.

POSITIVE DISPLACEMENT--Equal reaction to an action.

POUNDS--Unit of weight measurement equaling 16 ounces.

PRECAUTION--To be on one's guard.

PREFABRICATED--Already made.

PREHEATERS--Equipment used to heat something before it is used.

PRELIMINARY--Something that precedes.

PREOPERATION/PREOPERATIONAL--Before operating.

PRESSURE--Force exerted.

PREVENT/PREVENTING--To stop from happening.

PRIMARY--Main.

PRIMING--Filling with water.

PRINCIPAL--Most important.

PROCEDURE--Steps followed in a definite order.

PROGRAMMER--Controlling device used on boilers.

PROJECTING--Going beyond.

PROLONGED--To lengthen the time of.

PROPER--Right or correct.

PROTECTION--Guard against.

PROVIDE--To supply or support.

QUALIFIED--Complied with the specific requirements.

QUALITIES--Peculiar and essential characteristics.

QUARTERLY--Four times a year, three months or 90 days.

QUESTIONABLE--Doubtful.

RECOMMEND--To attract favor to.

RECTIFICATION/RECTIFYING--To make unidirectional.

REDUCE/REDUCING/REDUCTION--Decrease or make smaller.

REFRACTORY--Heat resisting nonmetallic ceramic material.

REGENERATIVE--Ability to form or create again.

REGULATE/REGULATING/REGULATOR--To control the flow of.

RELAY--Electrical device used to delay the flow of current.

REMOVED--Taken away from.

REPAIR--Fix or put back into condition.

REPLACE/REPLACEMENT--Substitute.

REQUIRE/REQUIRED/REQUIREMENTS--Needed or essential.

RESIDUE--Remains of.

RESISTANCE--Opposition against.

RESPIRATORY--Breathing.

REVOLVING--Turning around on an axis.

RIVETED--Fastened or united with rivets.

ROTATION--The turning of a body on an axis.

SAFETY--Condition of being safe from or causing hurt, injury or loss.

SCANNER--Control component used to sense flame.

SEDIMENT--Settlings of impurities.

SEQUENCE--The order of progression.

SETTING(S)--Material that covers an inside surface of a boiler furnace.

SHALLOW--Opposite of deep.

SHRINKAGE--Amount of decrease in size.

SIMULATANEOUSLY--At the same time.

SOLUTION--Liquid containing a dissolved substance.

SPALLED/SPALLING--The flaking and chipping of brick surfaces.

SPECIFICATIONS/SPECIFIED--Detailed precise presentation of something.

STANDARD--Something established as a rule for measuring quantity, weight, extent, value or quality.

STATIONARY--Fixed, immobile.

SUFFICIENT/SUFFICIENTLY--Enough.

SUPERHEATER--Tubes in steam boilers that add extra heat to the steam before exiting the boiler.

SUPERVISOR--Administrator in charge of.

SUSPENDED--To maintain from falling or sinking.

SYSTEM(S)--Regularly interacting or interdependent group forming a unified whole.

TAPERED--Becoming gradually smaller toward one end.

TEMPERATURE--A measurement of heat in degrees Fahrenheit or Celsius.

THERMODYNAMIC--A steam trap operated by the dynamics of heat.

THERMOHYDRAULIC--A feedwater regulator operated by expansion and contraction of water.

THERMOSTATIC--A feedwater regulator operated by the expansion and contraction.

THICKNESS--Measurement from one side through to the other.

THOROUGHLY--Completely.

THROTTLING--To prevent or check activity of.

TURBINE--Rotary engine actuated by the reaction or impulse of a current of fluid or gas.

TYPICAL--Common.

UNCONDENSED--Not condensed.

UPWARD--From lower to higher.

VACUUM--Devoid of matter.

VALVE--Mechanical device used to stop or permit the flow of fluids or gases.

VENTILATE/VENTILATION--To air out.

VERIFICATION--Act or process of confirming.

VERTICAL--In an upright or up-and-down motion or position.

VIBRATION--Periodic motion in alternately opposite directions.

VOLTAGE--Unit of electrical potential or potential difference.

WATER--Contains two parts hydrogen and one part oxygen, expressed as $H_2O$.

WATER COLUMN--A steam boiler external fitting used to prevent fluctuations of water in the gauge glass.

WITHDRAWING--Taking out or away.

YEARLY--Once a year.

## EXTERNAL BOILER MAINTENANCE

### OBJECTIVES

Given proper procedures and with team member, replace and test safety valve with instructor assistance.

Given instructions and with team member, replace gauge with insructor assistance.

Following given procedures and with team member, clean water column and gauge glass with instructor assistance.

Using information, answer questions about inspection and replacement of soft plugs to 80% accuracy.

Given proceuures, check and clean boiler fireside with instructor assistance.

Given procedures and working with team member, repair and replace refractory with instructor assistance.

### INTRODUCTION

External boiler maintenance is only a part of the total maintenance that is done on steam boilers. The following items will be covered under external maintenance: maintenance on safety valve, replacing steam gauges, maintenance on water column and gauge glass, inspection and replacement of soft plug, checking and cleaning fireside, repair or replace refractory material.

External boiler maintenance can be divided into two areas, the first is maintenance on external fittings of steam boilers, the second is external maintenance on the fireside of steam boilers.

### INFORMATION

## EXTERNAL MAINTENANCE ON BOILER FITTINGS

### Safety Valve

The safety valve is the most important boiler fitting. To make sure that it will work properly the safety valve must be inspected, tested, and if needed replaced.

Preventive Maintenance Inspection. The preventive maintenance inspection of the safety valve is performed on a daily, monthly and annual (yearly) basis. We will talk about each one separately.

DAILY INSPECTION. Check for deterioration or inadequate support of safety valve exhaust piping. Make sure that the valve discharge does not endanger personnel. Steam leakage through safety valve may indicate defective seats or lodged scale.

MONTHLY INSPECTION. Test each safety valve by gently raising the valve off the seat by hand (using the valve lifting lever). Keep the valve open wide for at least 10 seconds to blow dirt and scale clean from the seat. Close the valve by suddenly releasing the lever. This test is done only when the boiler pressure is from 80 to 85 percent of the present popping point.

ANNUAL INSPECTION. Observe popping pressure when the valve pops normally. The valve is popped by the steam pressure generated in the boiler. If the difference between the actual and the present popping pressure is above 5 psi, test the steam pressure gauge. If the gauge is correct, notify your superior so that the valve can be reset by an authorized person.

### Replacement of Gauges

The steam gauge is replaced only after it is found to be defective. To determine if the steam gauge is defective the steam gauge must be tested annually.

The steam gauge is tested by using either the dead weight tester, or air pressure. If the steam gauge is found to be defective and cannot be calibrated to the correct pressure, then it will be replaced.

The Bourdon is the main type of steam gauge. Bourdon gauges should never be connected directly to steam or subjected to high temperatures. A proper gauge siphon called a siphon loop used to condense the steam is used. A water leg is sometimes used in the place of the siphon loop. A gauge cock must be installed next to the gauge and provisions for testing should be made by installing a test gauge connection.

### Water Columns and Gauge Glasses

WATER COLUMN. Annually (yearly) the water column will be dismantled, cleaned, and all parts will be inspected (valves, alarm linkages, floats, alarms, etc.). Replace or repair damaged, pitted or worn parts as required. As a preventive maintenance requirement, the water column will be blown down once each shift. Blowdowns help to remove scale, dirt or any solid matter which could plug the gauge glass connections and cause a false indication.

GAUGE GLASSES. Gauge glasses have small amounts of maintenance that will be performed. Repair all leaks promptly. Repack gauge valves and water glasses when required, using the packing rings and washers recommended by the manufacturer.

When installing new packing, add graphite to the packing washer to prevent the glass from twisting when the nut is tightened. Do not use loose packing in water glass stuffing boxes. Regrind valve seats and discs as required.

Blowdown gauge glasses only when necessary, and then do it gently. Excessive blowing down of gauge glasses roughens the glass. Usually, when the water column is blown down the gauge glass is sufficiently cleaned.

### Inspection and Replacement of Soft Plugs

Fusible plugs are hollow bronze plugs filled with an alloy (mostly tin) which has a low melting point (usually 450° - 500°F). If the water level drops below the plug, the tin melts and blows out, allowing steam to come thru the soft plug. The soft plug is therefore used as a warning device.

The boiler has to be taken out of service to replace the plug. Old plugs should not be refilled with tin alloy for re-use.

Inspection of the soft plug will be done during boiler inspections. Scrape the surface clean and bright. Replace it if the metal does not appear sound.

Replace soft plugs at least once a year.

## EXTERNAL MAINTENANCE OF FIRESIDE

Regardless of how efficient you are at firing a boiler, carbon will form on the external surfaces (firesides). Part of your job will be to remove the carbon.

### Safety Precautions

Empty the boiler after it has been shut down and the furnace has cooled enough to permit a man to enter and remain safely. (The boiler water temperature will then be below 200°F.) Proceed as follows:

1. Take proper precautions before sending a man into any part of the boiler. Provide workers with goggles and respiratory protection.

2. Open access doors to the furnace and gas passages. Tag all controls and close and tag all valves, drains, and blowdown valves connected with similar parts of other units under pressure. This procedure prevents steam or hot water from entering the unit. Be sure that the tags remain until an authorized person removes them.

3. Inspect tools for broken parts before use.

4. Check electrical equipment for the proper grounding plug and frayed wires.

5. Keep area clean as possible while working, remove clutter from floor, etc.

## CLEANING OPERATING BOILERS

SOOT BLOWERS. Soot blowers are used to remove soot, ash cinders, and slag deposits from boiler heating surfaces. Soot blower systems consist of: soot blower units permanently mounted in the boiler setting, or boiler supporting structure; a piping system to handle the blowing fluid (usually steam or air); and a control system (manually or automatically operated valves).

SOOT BLOWER TYPES. Two main types of soot blowers are used in heating plants:

1. Stationary Element. This type is used to remove slag and soot deposits on shallow banks of tubes. The element is fixed.
2. Rotary Element. This type is used to clean tubes in the different boiler passes. It can be rotated through a preset blowing arc.

MECHANICAL SOOT BLOWER. Mechanical soot blowers consist of a blower element and a head.

Head. The head admits the blowing fluid to the element. In the rotating type of soot blower, the head rotates the element through a preset blowing arc. Figure 1-1 illustrates a type of soot blower in which the admission of the blowing fluid is controlled by a cam-actuated valve located in the head. This valve is operated when the element is turned. The blowing arc can be adjusted to avoid striking and damaging baffles, drums, and headers. The head can be supported by a wall box installed in the boiler setting, or by the steel boiler-supporting framework. Springs and sliding fits, or a flexible joint between the head and the element, normally take care of relative movement between the head and the wall box.

Elements. Soot blower elements are tubes which have a number of nozzles through which the blowing fluid flows. The nozzles are designed and spaced along the element to provide an effective cleaning effect. During installation, it is important to check the position of the nozzles relative to the boiler tubes to prevent direct impingement. Unless this precaution is observed, the high velocity of discharge through the nozzles may damage the tubes. Elements are made of plain, calorized, or alloyed steels, according to the temperature to which they are to be subjected. They are supported at regular intervals by bearings clamped to the boiler tubes. The design and spacing of the bearings depend on the temperature of the zone where they are to be located.

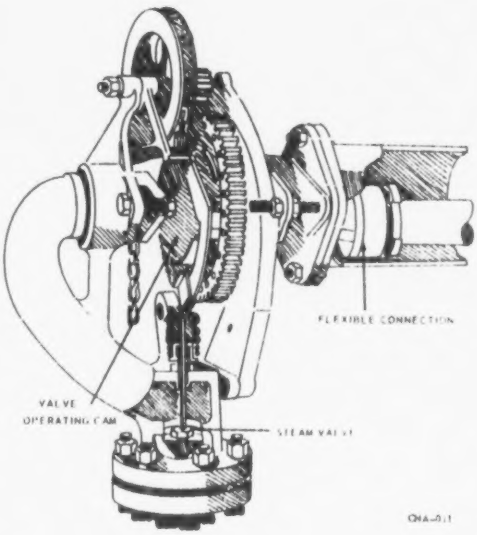

Figure 1-1. Valve-In-Head Soot Blower

Cleaning Procedures for an Idle Boiler

To safely and efficiently clean an idle boiler, you should perform these steps:

1. Remove the burner and perform preventive maintenance.
2. Cap off the fuel line.
3. Provide ventilation, goggles, gloves, coveralls and respirators.

4. All electrical equipment used must be grounded (have the 3-prong plug).

5. Use a long-handled wire brush that will pass completely through the tube of a fire tube boiler.

   NOTE: When you start the brush, make a complete pass, to not try to change direction when the brush is inside the tube.

6. Brush each tube until clean (should be shiny).

7. Clean all flat heating surfaces.

8. If there is soot, clean it off. (1/16" soot = approximately 5% heat loss.)

9. When laying up the boiler for summer, pass a mineral oil-soaked rag through the tubes.

10. Remove all soot from boiler by most convenient method; dust pan, brooms, vacuum cleaner, etc.

## CHECK AND CLEAN FIREBOX, SMOKE BOX, AND STACK

### Stack

The stack should be cleaned quarterly, a vacuum cleaner or some other convenient method should be used. Access can usually be gained through clean-out doors located at the base of the stack.

### Smokebox

The smokebox can be cleaned by vacuum cleaner or any other convenient method. Most large boilers are equipped with rear observation doors or some other means of access to the smokebox. Make sure the observation door is secured tightly before starting the boiler.

### Firebox

Firebox walls of space heaters, furnaces, and boilers are usually lined with refractory material such as firebrick, insulating brick, refractory mortar, etc. A refractory lining in a horizontal type boiler is shown in figure 1-2. Refractory is a heat-resisting, nonmetallic, ceramic material. When a boiler is shut down for repairs or lay up, the firebox should be cleaned to remove soot, loose slag and deposits. After cleaning a good inspection of the refractory is in order to locate loose or sagging brickwork that may be in need of replacement or repair.

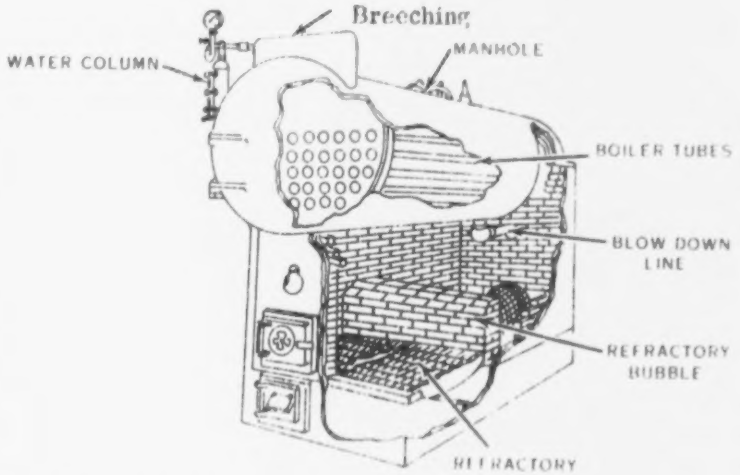

Figure 1-2. A Refractory Lining in a Horizontal Type Boiler

## INSPECT FIRESIDES

Inspection of boiler firesides should be performed whenever the boiler is shut down for extended periods of time. Materials needed for repair or replacement can be ordered, and work can be scheduled to conform with the workload of the shop. After completion of a job, the work should be inspected to insure it conforms with the manufacturer's specifications.

## REFRACTORY LININGS

The purpose of a refractory lining is many fold and may be summed up by the following statements:

1. It protects the furnace or boiler lining.
2. It assists in maintaining a high combustion chamber temperature.
3. It helps to accelerate the rate of combustion.
4. It prevents the escape of heat through the walls of the combustion chamber.
5. It serves to protect boiler drums, headers, waterwalls, etc., from direct contact with the flame and from radiant heat.
6. It resists the cutting and abrasive action of a flame and the unburned particles of fuel.
7. It possesses uniform expansion and contraction characteristics within operating limits.
8. It resists fusion at a temperature to which it is exposed.
9. It withstands heavy pressures from other brickwork or boiler parts at high temperatures.
10. It resists spalling. Spalling is the flaking and chipping of brick surfaces.
11. It resists slagging. Slagging is the fusion of mineral residue such as ash with brick surfaces.
12. It resists vibration caused from panting and ignition explosions.

### Factors Effecting Linings

The life of a furnace or boiler lining is influenced by many factors, three of which are listed below:

1. High furnace temperature.
2. Rapid changes in temperature.
3. Vibration or panting of a boiler. (Lack of air in combustion chamber.)

The first factor may be offset by using the best grade of refractory material available.

The second factor can be reduced to a minimum by intelligent boiler operation. A boiler should never be heated as fast as possible. It should be fired at low fire to allow the brickwork to warm up slowly. The same procedure applies to the cooling of a boiler. However, in case of emergency, it may be necessary to ignore these precautions but continued practice should not be allowed since brickwork troubles will soon develop.

The third factor is sometimes difficult to correct. Vibration and panting of boilers may be due to the method of operation. Design of the combustion chamber, type of fuel used, etc. Such malfunctions may be determined only by careful analysis of operating methods and complete inspection of the boiler unit.

### Types of Refractory Materials

There are many different types of refractory materials on the market today. Each manufacturer recommends their product and lists various reasons why such products are superior to others. However, the heating specialist should know the use of firebrick, insulating brick, ordinary brick and mortar. A good quality of materials should be used. Refer to manufacturer's instructions and blueprints when making repairs or replacements.

### Insulating Block

Insulating block is made from uncalcined diatomaceous earth and a bonding material to make it hold its shape. It will not stand exposure to direct flame. But it withstands temperatures up to 1500°F. It is used as the first insulating layers against the metal casing. Various methods are used to tie the block to the casing. It is lightweight and porous and must be handled carefully. Standard size of insulating blocks are 1" x 6" x 18" or 1" x 6" x 36".

### Insulating Brick

Insulating brick is made of fire clay and possesses a high insulating value and ability to withstand high temperatures without shrinkage. Insulating brick is not designed to be used in direct contact with the flame and where the hot gases exceed 2600°F. It is available in all standard 9-inch series shapes.

Insulating brick is porous, light in weight, and possesses a heat conductivity of less than one third that of heavy firebrick. Due to its excellent insulating qualities, brick of this type is frequently used between the inner firewall and the outer wall of a boiler for the purpose of reducing heat loss from the combustion chamber. Because insulating brick is soft and porous, it must be handled carefully to prevent breakage.

### Standard Firebrick

Standard firebrick is made chiefly of refractory clay. It may be either hard and dense or comparatively soft depending on the treatment during its manufacture. Firebrick of this type is used in direct contact with the flame and withstands a temperature of approximately 3000°F before it will melt or fuse. See figure 1-3.

Standard firebrick is manufactured in various shapes and sizes. The firebrick shown in figure 1-3 is 9-inches long, 4 1/2-inches wide, and 2 1/2-inches thick. However, all other shapes of firebrick are usually 9-inches long with various widths and thicknesses to fit the spaces desired during refractory construction. See figure 1-4.

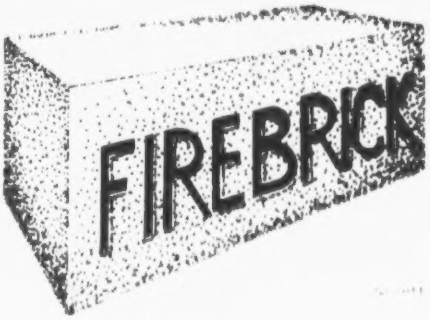

Figure 1-3. A Standard Firebrick

### Plastic Firebrick

For normal refractory work, standard firebrick is generally used, but plastic firebrick is recommended for emergency patching and building furnace openings. Plastic firebrick is unburned brick in a stiff plastic condition. Because of its plastic nature, it can be pounded into a cavity or space where a prefabricated firebrick would not fit unless the cavity was chiseled to the proper dimensions. The fusion point of plastic firebrick is practically equal to that of the standard firebrick, but due to the additional moisture in the plastic firebrick, a greater degree of shrinkage will result.

### Building Brick

Standard building brick is made by molding a mixture of sand and clay and baking the mixture in a kiln. Building brick is usually used to form the outside portion of the boiler combustion chamber wall. The brick affords protection to the insulating brick and adds strength to the construction of the boiler assembly.

Ordinary building brick is 8-inches long, 4-inches wide, and 2-inches thick. Brick of this type is less resistant to high temperatures and should not be used as a substitute for firebrick or insulating brick.

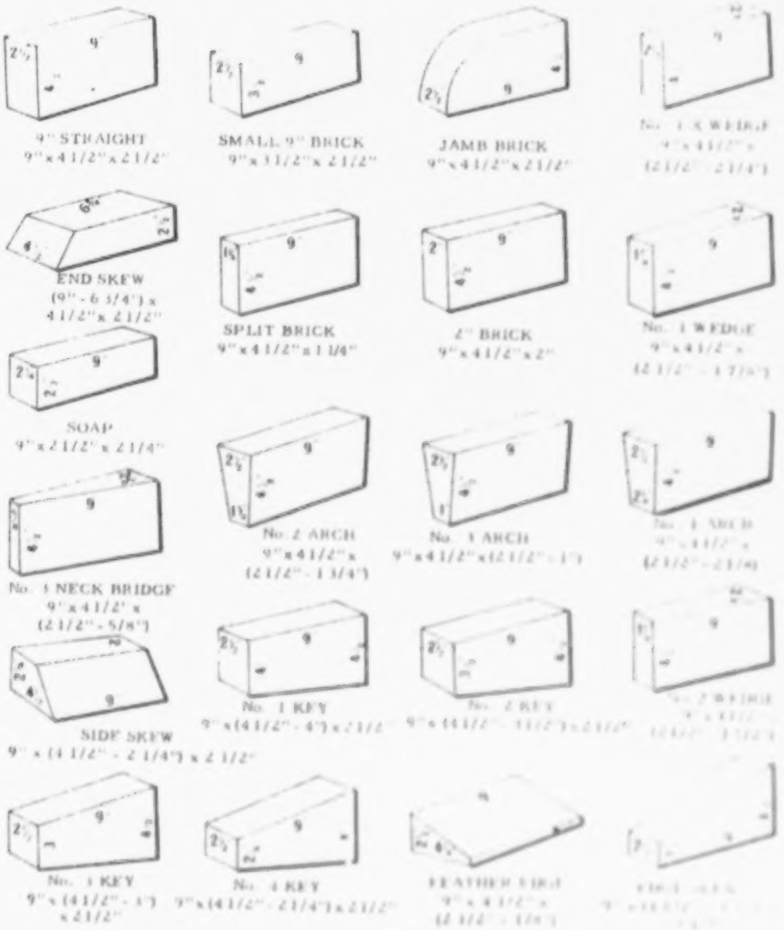
9" STRAIGHT
9" x 4 1/2" x 2 1/2"
SMALL 9" BRICK
9" x 3 1/2" x 2 1/2"
JAMB BRICK
9" x 4 1/2" x 2 1/2"
No. 1-X WEDGE
9" x 4 1/2" x
(2 1/2" - 2 1/4")
END SKEW
(9" - 6 3/4") x
4 1/2" x 2 1/2"
SPLIT BRICK
9" x 4 1/2" x 1 1/4"
2" BRICK
9" x 4 1/2" x 2"
No. 1 WEDGE
9" x 4 1/2" x
(2 1/2" - 1 7/8")
SOAP
9" x 2 1/2" x 2 1/4"
No. 2 ARCH
9" x 4 1/2" x
(2 1/2" - 1 3/4")
No. 3 ARCH
9" x 4 1/2" x (2 1/2" - 1")
No. 1 ARCH
9" x 4 1/2" x
(2 1/2" - 2 1/8")
No. 3 NECK BRIDGE
9" x 4 1/2" x
(2 1/2" - 5/8")
No. 1 KEY
9" x (4 1/2" - 4") x 2 1/2"
No. 2 KEY
SIDE SKEW
9" x (4 1/2" - 2 1/4") x 2 1/2"
No. 3 KEY
9" x (4 1/2" - 3")
x 2 1/2"
No. 4 KEY
9" x (4 1/2" - 2 1/4") x 2 1/2"
FEATHER EDGE
9" x 4 1/2" x
(2 1/2" - 1/8")

Figure 1-4. Various Firebrick Shapes and Sizes

Baffle Mix or Castable Refractory

Castable refractory is a granular material composed of calcined flint clays, refractory clays, and lumite cement. Castable refractory is used around burner ports, peepholes and for patchwork. Castable refractory can be safely used any place where the temperature does not exceed 3000°F. Castable refractory must be molded to shape with a form (much like concrete).

## Plastic Chrome Ore

Plastic chrome ore (PCO) is quite different from the fire clay base materials used in construction of furnace walls. It is mined chrome ore called chromite. Chromite is mined in Cuba, South Africa, Turkey, Russia, and Caledonia. The material is used as mined.

Plastic chrome ore is used for baffles to direct the gases of combustion and to protect headers, drums, and areas where high temperatures are not desired. For instance, the temperature of the surface exposed to the flame may be 3000°F but the temperature at the point of contact with the tubes only a few hundred degrees. This is a drop in temperature of about 2500°F in a thickness of about 1/2 inch, and it is doubtful that any clay or other type of material would withstand this treatment.

## Plastic Firebrick Used for Repairs

Plastic firebrick may also be used as a refractory material for linings. However, its length of service is much less than that of standard firebrick.

When laying chunks of plastic firebrick just as they are taken from the can, the chunks should be rammed tightly into place, preferably in horizontal layers. In general, the more solidly the section of plastic is rammed together, the better it will be. The plastic section then should be vented with three-sixteenth inch holes extending through the plastic and not more than one inch apart. This allows deeper heat penetration during the vitrification process and also permits the escape of steam formed from the moisture in the plastic.

Vitrification is the process of changing to a glass-like structure. It is not recommended to trowel the surface of a new plastic section, since this tends to prevent the escape of steam during the vitrification process.

The plastic section should be held in place with as many anchor bolts as would have been provided had standard firebrick been used instead of plastic firebrick.

The plastic section should be air dried from forty-eight to seventy-two hours depending on the humidity in the atmosphere. As soon as practicable after air drying, the furnace should be fired with a low fire and gradually brought up to operating temperature. This permits vitrification to take place. Plastic requires a temperature of about 2900°-3000° for vitrification. Should any shrinkage cracks open up during this process, they should, if small, be filled with fire clay; if large, with plastic. If the plastic section is not vented, it will be necessary to bake it from twenty-four to thirty-six hours at a low temperature prior to vitrification.

## Mortar

Mortar is a mixture of fire clay, water, and sand. It is used for setting firebrick, insulating brick, and building brick when constructing boiler combustion chambers, walls, supports, etc.

Mortar should be uniformly fine when mixed. Any lumps in the mixture should be broken during the mixing procedure. Sufficient water should be added to the mixture so that when a sample of it is placed between two bricks and the top brick raised with the hand, the stickiness of the mortar should almost hold the bottom brick to the top brick. This consistency should be maintained during the process of bricklaying by stirring the batch of mortar at frequent intervals.

## Expansion Joints

Many combustion chambers constructed of bricks fail because no provision is made for normal expansion. This condition results in cracks in the brick joints and allows air to leak into the combustion chamber making it difficult to regulate combustion. Eventually, if too many cracks develop in the walls, the efficiency of the furnace would become very low.

To prevent combustion chambers from cracking due to expansion, it is necessary to install expansion joints in the combustion chamber brickwork. Figure 1-5 illustrates staggered expansion joints in the corner construction of a typical furnace wall. These expansion joints usually extend the height of the wall. Expansion joints are normally caulked with asbestos rope or other suitable material which allows movement of the bricks and still maintains an air seal at these points.

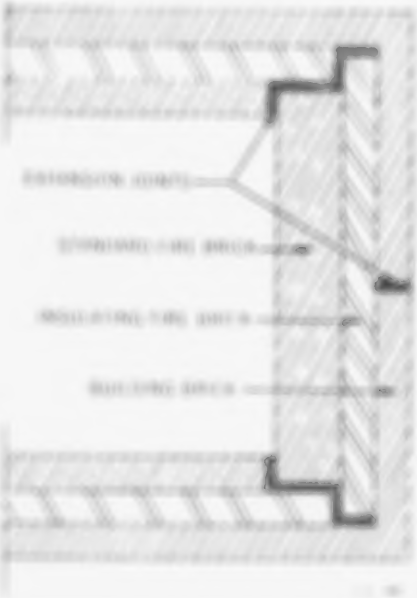

Figure 1-5. Typical Furnace Wall

Tying Brick Courses

Sometimes it is desirable to tie standard firebrick to the outer brick wall. For this purpose, it is necessary to procure notched firebrick and tying irons and construct the wall in a manner shown in Figure 1-6.

This method is by no means the only one. Some brick courses of a wall may be held together by bolts which extend through the complete wall.

BOILER REFRACTORY REPAIR

Minor Repairs

Plastic firebrick is especially useful for quick patchwork, such as replacing spalled brick faces. When patching spalled brick faces, be sure to remove all ash, slag, or foreign material on the remaining brickwork. Without removing an excessive amount of the good brick make the area to be patched as rough as possible. A patch of this type should be made only as a temporary measure; it will not last for any great length of time.

For a more permanent job, the firebrick should be removed back to the insulating brick. For large patches, use as many firebricks as possible and build in the remainder of the wall section with plastic.

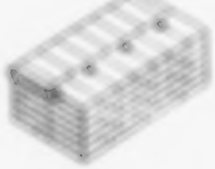

Figure 1-6. Tying Firebrick to Outer Wall

Major Repairs

After an inspection of the furnace has been made, and it is determined that minor repairs will not suffice, plans should be made to completely rebuild the damaged wall or floor area.

If a set of prints showing the location of expansion joints and the number of bricks of each type to be used in the furnace is not available, the man in charge should count the number of bricks needed and obtain the exact location of all expansion joints. The availability of material needed for the job should be checked before the wall or floor is removed.

After the damaged wall or floor is removed the furnace should be cleaned and inspected. If the furnace is of steel construction, the furnace should be checked for proper alignment and repainted before new brick is installed.

The first material installed is the 2" x 6" x 36" insulating block. This is laid flush against the floor or wall making sure to always break joints. No cement or mortar is used. Extreme care should be used so as not to break any corners off the insulating block. When corners are broken, blocks should be sawed off square.

The second material to be installed is the 2 1/2" x 4 1/2" x 9" insulating brick. It isn't required to use mortar for insulating brick, if mortar is used, it should be mixed to a thin dipping consistency. The second row of insulating brick should be rubbed against the first row making sure to obtain a tight joint. Continue doing so until the course is finished. Where the expansion joint is to be located, a split insulating brick 1 1/4" x 4 1/2" x 9" should be used, with a 1 1/4" x 4 1/2" x 9" firebrick laid on top. The reason for this is to prevent hot flames or combustion from burning out the insulating brick behind an expansion joint.

The final material to be installed is the 2 1/2" x 4 1/2" x 9" firebrick. Much care should be taken when laying this course of brick. The work should be under constant, experienced, and intelligent supervision. The brick should be laid up even and straight making sure that the seams between each brick are as small as possible--not over 1/16 inch. Inspect for flaws and insure that the dimensions are even. Choose bricks with the best edges and without broken corners. Dip the brick in mortar and allow excess to drip off. DO NOT PLACE ANY MORTAR ON THE WALL OR BRICK WITH A TROWEL. THE MORTAR ADHERING ON DIPPING IS ALL THAT IS USED. Place the brick quickly into position against the wall and pound into place with a wooden mallet until no more mortar can be forced out of the joints. The thickness of the joints will depend upon how even the surface of the firebricks are, but the joints should never exceed 1/16 inch. The furnace face of the bricks should all be in the same plane without any of the edges projecting and thereby exposing them to the flame. This would cause rapid deterioration of the brick.

## SUMMARY

The firebox lining protects the boiler casing and assists in maintaining a high furnace temperature because of it's ability to retain heat for relatively long periods of time. The refractory material must be kept clean and in good repair.

## QUESTIONS

1. What is boiler refractory?

2. What is the purpose of the soot blower?

3. What is used to clean the tubes of a fire tube boiler?

4. List three important factors that can affect the life of furnace or boiler lining.

5. In general, what is plastic firebrick used for?

6. What is building brick used for in boiler construction?

7. How often are water columns blown down?

8. How often is the gauge glass blown down?

9. What is the purpose of soft plugs?

10. What is used to attach a steam gauge to the boiler?

REFERENCE

AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems

# INTERNAL BOILER MAINTENANCE

## OBJECTIVES

Given proper procedures and with team member, maintain boiler waterside components with instructor assistance.

Given information and with team member, inspect for external corrosion with instructor assistance.

Following step-by-step procedures and with team member, perform a hydrostatic test with instructor assistance.

Given information and with team member and following step-by-step procedures, make minor tube repair with instructor assistance.

## INTRODUCTION

Internal boiler maintenance is the second part of the total maintenance that is done on steam boilers. The first part of the total maintenance was previously covered in the first unit. The following items will be covered under internal maintenance: maintaining waterside components, inspection for internal corrosion, hydrostatic test, and minor tube repair.

The internal surfaces (watersides) of the boiler must also be cleaned so that scale does not form and harden. The scale will insulate the tubes resulting in burning them out.

## INFORMATION

## INTERNAL BOILER MAINTENANCE

Before you enter the waterside of a boiler for inspection, cleaning, or repair, the boiler must be shut down. The following procedures will explain proper shutdown.

### Shutting Down Procedures

1. Operate the soot blowers before shutdown, while the boiler is still in operation (if applicable).
2. Gradually reduce the load on the boiler by cutting down the fuel and air supply.
3. Keep normal water level.
4. When boiler load reaches about 30 percent of rating, change the combustion control and the feedwater control from automatic to manual operation.
5. Before completely stopping the fuel supply, open the drain valves at the steam and nonreturn valve, and the drain valve on the superheater outlet header. Be sure bypass valve around the nonreturn valve is closed.
6. When the load has been reduced as much as practical with the fuel burning equipment provided, shut off the fuel supply.
7. Continue operation of draft equipment until all fuel accumulations in the furnace have been burned and the furnace is thoroughly purged.
8. Shut down draft fans.
9. Close dampers, including air preheaters and superheater dampers.
10. Cool down the boiler at a rate not exceeding a 100°F drop in saturated boiler water temperature per hour. Excessive stresses in pressure parts can be set up if the rate of pressure and temperature change is excessive.

11. Drop boiler pressure by discharging steam through the superheater drain valve and the drain valve at the nonreturn valve. If boiler is losing pressure at a rate faster than required, throttle drain valves as necessary.

12. As soon as boiler pressure starts dropping, close the steam stop and nonreturn valve.

13. When the boiler no longer requires any feed and the nonreturn valve is closed, open the valve in the recirculating connection of the economizer.

14. When the drum pressure drops to 15 psig, open the drum vent valves.

15. If a regenerative air heater is provided, stop the rotor when the boiler exit gas temperature drops to 200°F.

16. Close feedwater stop and check valve.

17. The boiler can be drained when the furnace has cooled sufficiently for a man to safely enter and remain in the furnance. At this time, the temperature of the water in the boiler will be below 200°F.

18. Access and observation doors to the furnace and gas passages can be opened at this time. Tag all controls. Tag valves and open drains or blowdown valves connected with similar parts of the other units under pressure at the time to prevent steam or hot water from accidently entering the unit. Permit authorized persons only to remove the tags.

### Draining and Flushing a Boiler

Draining. Once the boiler has been shut down, it must be drained before entering. However, a boiler must never be drained until the water temperature is below 200°F. This precaution prevents baking the scale on the tubes and protects against leakage at seams or expanded joints.

Flushing: Immediately after draining, wash interior thoroughly to prevent sludge deposits on internal surfaces and remove all suspended solids, sediment, and loose scale. When the boiler has been drained, close all blowoff valves to prevent entrance of hot water and steam if other boilers can be blown down into the same blowoff system.

### Clean and Inspect Boiler Interior

Proceed as follows:

1. Remove manhole and handhole covers and ventilate the boiler before sending a man inside. Be sure to inform the persons concerned that the work is being done.

2. Station a man outside the access point to keep in communication with the men inside.

3. Use low voltage lamps, provided with suitable guards, when inside the boiler. Even 110 volts can be lethal under the low resistance conditions found inside a boiler. Therefore, all portable electrical equipment must be grounded and adequately insulated. Use extension cords that are designed for rough usage, keep them in good condition.

4. Look for signs of scale, oil, corrosion, abnormal wear, and abrasion of pressure parts.

5. Check condition of drum internals, feed connections, drains, blowdown connections, etc.

6. Check connections to water column, gauge glass, and steam pressure gauge.

7. Check tube ends for corrosion and leakage. If leaks are found, try re-expanding. If the tube has been rolled too thin or is in bad condition, replace it.

8. Clean the unit as required before returning it to service. Use electric, air, or water-driven turbine cleaners or chemicals.

Cleaning Tubes Mechanically

Cleaning Tubes. You can clean tubes mechanically or chemically. Different types of mechanical cleaners have been developed. In general, they consist of a motor-driven flexible shaft with a rotor, brush, or expanding cleaner. The motor, actuated by air, water, or electric power, drives revolving brushes, cutters, or toe heads through the tubes to dislodge scale or other deposits. Figure 2-1 illustrates the different types of tube cleaners.

When using a mechanical cleaner, move it at a uniform rate and never operate it continuously in the same position. If you don't, the inner surface of the tube may be ground away. With a water hose, wash down the loosened deposits to the lower cleanout points of the boiler and remove them. Finally, thoroughly clean the mud drums, steam drums, and headers.

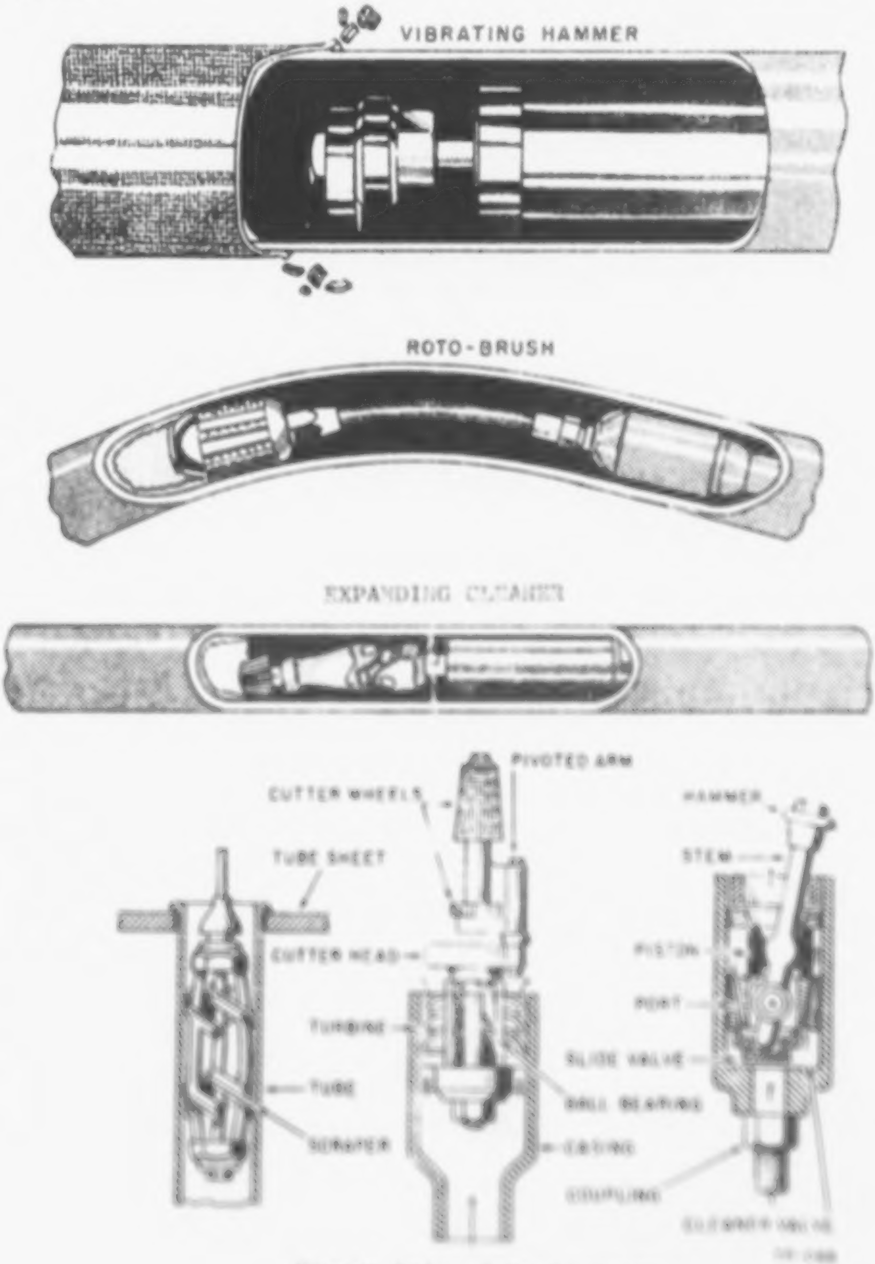
VIBRATING HAMMER
ROTO-BRUSH
EXPANDING CLEANER
PIVOTED ARM
CUTTER WHEELS
HAMMER
TUBE SHEET
STEM
CUTTER HEAD
PISTON
PORT
TURBINE
SLIDE VALVE
TUBE
BALL BEARING
SCRAPER
CASING
COUPLING
CLEANER VALVE

Figure 2-1. Tube Cleaners

You operate all cleaners in the same way. Start the cleaner rotating and insert it in the tube. Pass it slowly along until it comes out the other end of the tube. Immediately reverse the direction and bring the cleaner back through the tube and withdraw it. Don't stop the cleaner at any point in the tube as it may cut through the tube. Also be careful not to extend the cleaner too far out at the end of the tube.

After cleaning all the tubes, follow up by blowing them out thoroughly with a strong air jet. Then inspect to see if replacement of any of the tubes is necessary.

Chemically Cleaning Boilers

General. Boiling out removes grease, oil, dirt, and protective coatings from boiler heating surfaces. Chemicals are generally used to clean newly erected boiler units and others which have been extensively repaired or retubed.

Boiling Out Mixture. There are many different mixtures which provide enough cleaning action to do a good job. The following combinations are among the most common ones:

1. Combination No. 1. Use 2.5 pounds of trisodium phosphate and 2.5 pounds of caustic soda for every 1,000 pounds of water needed for normal operation.
2. Combination No. 2. Use 3.0 pounds of caustic soda and 3.0 pounds of soda ash per 1,000 pounds of water needed for normal operation.

Boiling Out Procedure: Some boiler manufacturers supply specific instructions for boiling out. These should be followed. For other units, proceed as follows:

1. Remove the regular water gauge glasses and install special glasses and gaskets. These are usually furnished by the water column manufacturer for boiling out purposes. Regular water glasses could be damaged in the boiling out process.
2. Thoroughly dissolve the chemical in lukewarm water. Use protective goggles, gloves, and clothing, since the chemicals and the solution are strongly alkaline and must be handled carefully. Have plenty of fresh water available for washing purposes if required.
3. Feed normal boiler feedwater into the boiler until it shows in the gauge glass.
4. Pour the chemical solutions into the boiler drum through a manhole or an opening in the top of the drum. An alternate procedure uses the chemical feed pumps and tanks. After pumping the chemical solutions, flush the system with boiler feedwater to make sure that the piping and pumps are free from deposits.
5. Feed water to the boiler up to the centerline of the water gauge glass.
6. With all drum and superheater vents wide open, slowly heat the boiler water to steaming temperature (212°F).
7. In superheater installations, close all drum vents at this point, leaving the superheater outlet header vent open.
8. If there is no superheater, leave only one drum vent open.
9. Slowly raise the boiler pressure to boiling out pressure (50 percent of normal operating pressure, unless otherwise recommended by the boiler manufacturer.)
10. Blow down the boiler once every four hours using all main blowdown outlets evenly. The amount of blow down should be equivalent to a drop of one-half a water gauge glass for each blowdown operation. After individual valves are blown, feed water to the boiler to keep the water level within safe limits. When the blowdown is completed, bring the water level back to normal and add chemicals, if required, to re-establish the concentration at recommended levels.
11. A boiling out period of 48 hours is usually sufficient for a medium sized unit. Take a sample of the blowdown water at the end of this period to determine by its condition whether the boiling out should continue. If the blowdown water is clean, end the boiling out.

12. Let the unit cool slowly until it can be drained safely. Then drain; refill it with clean water and drain again.

13. Open manholes and handholes and wash down drums and tubes with a water hose.

14. Make a careful internal inspection. If boiler still looks dirty, repeat the boiling out process.

15. After boiling out and flushing the boiler clean, replace the temporary water gauge glasses and gaskets with permanent regular equipment.

### Handholes and Manholes

Handholes and manholes allow access to the watersides of a boiler for cleaning and inspection. While a boiler is shut down for cleaning and repairs, the handholes and manholes should be carefully cleaned where the surface of the gaskets come in contact with the boiler surface as this will quickly damage the handholes and manholes beyond use if they are not kept clean. Do not forget to clean the inside surface of the boiler where the gasket makes a seal as this often becomes very pitted with corrosion. Use new gaskets when securing boiler.

## INSPECTION FOR INTERNAL CORROSION

While the boiler is open for cleaning, one important item that should be checked for is corrosion of the boiler tubes and internal boiler surfaces.

Corrosion in the boiler is caused by oxygen. Oxygen corrosion is the most common form of waterside corrosion. Oxygen corrosion causes the metal and the tubes to become pitted. This is known as oxygen pitting.

Inspection procedures will be done whenever waterside is opened for cleaning, using a flashlight. Report excessive amounts of oxygen pitting to your supervisor for corrective procedures.

## BOILER INSPECTIONS

Before boilers are inspected, clean fireside, waterside, insure refractory and pressure part repairs have been completed.

### Inspection Standards

Qualified boiler inspectors will inspect boilers, accessories, and piping to determine the condition of the boilers and safety devices and to determine that boilers and safety devices are suitable for safe operation. Inspections will conform to the procedures set forth in the latest edition of the National Board Inspection Code published by the National Board of Boiler and Pressure Vessel Inspectors, Columbus, Ohio (Cost $1.00).

> NOTE: When the United States has sole jurisdiction over leased facilities, these instructions supersede any existing state or municipal codes governing boiler inspection.

### What Equipment Will be Inspected

MANDATORY INSPECTION. Steam boilers operating above 15 psi and high temperature hot water heating boilers operating above 160 psig will be inspected as prescribed by this section. Inspection of high temperature hot water boilers (not domestic water heaters) includes inspection of the expansion drum as well as the water tubes, headers, furnace and safety devices.

### Obtaining Inspection Service

1. The Defense Supply Agency, Defense Contract Services District, administers contracts each year for the services of a qualified company to provide boiler inspections at all Air Force bases within the Continental United States (excluding Alaska and Hawaii). For many years, the Hartford Steam Boiler Inspection and Insurance Company, Hartford, Connecticut, has provided this service.

2. Special inspections (outside the scope of the contract required by these instructions are considered necessary by major commands or base civil engineers) may be arranged through the Defense Supply Agency, Defense Contract Administration Services District, Cincinnati, Ohio.

3. If the company under contract to furnish boiler inspection service cannot make a special or emergency inspection, the base civil engineer may hire a recognized insurance company or a boiler inspection agency that specializes in such work. (An installation employee may not make such special inspections.)

4. The contract will provide the following five types of inspections when they are included in the annual schedule submitted by the major command.

   a. Type "A"--Internal and external inspection.

   b. Type "B"--Internal and external inspection, followed or preceded by external inspection while boiler is under hydrostatic test.

   c. Type "C"--External inspection while under steam pressure or filled with water. (Boiler will be under pressure for this inspection.)

   d. Type "D"--External inspection while under hydrostatic test.

   e. Type "E"--Internal and external inspection of expansion tanks used with high temperature water boilers.

5. Overseas and other off-continent commands are authorized to employ qualified and competent boiler inspectors to perform the inspections. These inspectors will not be supervised by personnel at base level. They will prepare AF Form 1222, "Boiler Inspection Report," on each boiler inspected and submit it to the Director of Civil Engineering of the appropriate major command. Detailed comments on these reports will be made by an attached memorandum.

The boiler inspector will make the types of inspections requested in the annual schedule submitted by the major command to the Defense Supply Agency, Defense Contract Administration Services District, Cincinnati. If an inspector determines that an additional inspection is necesary, the base civil engineer will authorize him to perform it before he leaves the base. However, such additional inspection will not constitute authority to delete subsequent scheduled inspections. The following inspections are required as a minimum.

1. Steam boilers assembled on the site require a type "B" inspection before they are placed in initial operation.

2. Steam boilers assembled at place of manufacture and stamped with approval of a qualified inspection agency (such as the Hartford Steam Boiler Inspection and Insurance Company): a type "B" inspection, after manufacture and before being placed in initial operation.

3. All Steam Boilers: Twice annually a type "A" inspection first and approximately six months later, a type "C" inspection.

4. Steam boilers in questionable condition, used boilers reinstalled, boilers which have had major repairs, recommended by the boiler inspector or required by the base civil engineer: a type "B" inspection before being placed in service.

5. New HTW (High Temperature Water) boiler installations: a type "B" inspection before operation.

6. Other HTW boilers: a type "A" inspection annually.

7. Expansion tanks: a type "E" inspection annually.

Boilers out of operation indefinitely need not be inspected by the inspecting agency. However, they should be inspected annually by base civil engineer personnel to evaluate visible deterioration and renew protection against corrosion, if necessary. Also, a boiler that has missed an inspection period must be given the appropriate inspection before it is placed in operation again.

The hydrostatic pressure used during a type "B" or type "D" inspection will be one and one-half times the pressure setting of the safety valves. If the safety valve setting has been lowered, it will not be raised without the approval of the boiler inspector. Boiler inspectors will insure that the boiler, accessories, and adjacent piping are in condition to be operated at pressures up to the safety valve setting.

Before leaving the base, the inspector will orally report any serious defects to the base civil engineer (or his representative). Boilers found to be in dangerous condition will not be operated until repaired.

Hydrostatic Test

A hydrostatic test is a water pressure test to prove the strength and tightness of a boiler.

After repairs are made, a hydrostatic test is performed on the boiler to check for leaks around rolled and beaded areas. Should any leaks be found, reroll tube or tubes that are leaking making sure not to overroll.

NOTE: Hydrostatic pressures are 1 1/2 times the safety valve setting.

The boiler is the principal and most costly unit in a central boiler plant. Preventive maintenance of the unit represent the difference between a normal useful life of fifty years or a short life with much time lost for repair and possible injury to operating personnel.

All boilers have general characteristics and need similar care. General care of the boilers follows two rules: stop leaks and keep the boiler clean. One of the boiler inspections required to determine its condition is the hydrostatic pressure test. This study guide will provide you pertinent information regarding this test under the following main topics:

NOTE: These preparations must be made before the boiler inspector arrives on the base.

1. Provide a hand pump for the hydrostatic pressure test if the boiler feed pump will not deliver one and one-half times the pressure at which any safety valve is set.
2. Make sure that Fire Surfaces of Boilers are reasonably clean. Use a tube brush to remove soot from tubes, and a wire brush to remove soot from the tube sheets and firebox. If the installation burns coal, remove the grate bars and clean the firebox plates along the grate line until the bare metal is exposed. Take care not to damage metal with sharp tools.
3. Provide gags to prevent safety valves from lifting when hydrostatic pressure is applied. If hydrostatic pressure tests on more than one boiler are contemplated, provide sufficient gags for all safety valves of the boilers to be tested.
4. Permit boilers taken off line for inspection purposes (including firebox and settings) to cool before they are drained. Immediately after draining, wash them thoroughly on the inside to prevent sludge deposits on internal surfaces, and remove all suspended solids, sediment, and loose scale.
5. Fill boilers scheduled for hydrostatic pressure test with water at a temperature between 70° and 100°F, apply a preliminary pressure of 15 to 20 pounds less than working pressure, to insure that all test equipment is in proper working condition.
6. If the boiler to be tested is on a common header with a second boiler and the latter is to be kept in operation throughout the test, equip the steam pipe between the two boilers with two valves and a drain or a blind joint.
7. Have available a supply of gaskets for manholes and handholes, and suitable wrenches for removing manhole and handhole covers.
8. Replace damaged and improper fusible plugs.

9. If insulation conceals manufacturer's inscribed data, remove the lagging and clean the surface carefuly so that die-cut letters and figures can be read easily.

10. Assign a qualified boiler plant operator to assist the inspector through the tests.

11. If boiler gauges and controls are not designed for a pressure equal to the pressure of the proposed tests, remove them and plug the openings, unless cutoff valves are present.

## BOILER TUBE REPAIR

There are times when the boiler tubes must have some kind of repair work performed on them. The repair work is classified either as minor or major, each one will be covered.

### Minor Tube Repair

Minor tube repair consists of rerolling a leaking tube using a tube expander. If rerolling a boiler tube does not stop the leak then welding a fire tube can be employed to stop the leak, or to prevent damage to the tube. In a water tube, the tube can be plugged using a plug made of brass or steel. This method should not be used for extended periods of times.

### Major Tube Repair

Major tube repair consists of removing and replacing a tube or tubes.

### SUMMARY

Before performing waterside maintenance be sure to chain and tag stop valves, feed valves and blowdown valves in the closed position and electrical switches in the open position.

Boilers should hold a hydrostatic test of 1 1/2 times the safety valve setting.

Qualified boiler inspectors will inspect boilers, accessories and piping to determine the condition of the boilers and safety devices and to determine that they are suitable for safe operation.

All steam boilers operating above 15 psi will be inspected twice annually; a type "A" inspection first and approximately six months later, a type "C" inspection.

### QUESTIONS

1. What safety precautions are observed prior to entering pressure parts of boilers?

2. What are the methods of cleaning water tubes in the boiler?

3. Which boilers must have official inspections?

4. What are the two types of boiler inspections?

5. What is the frequency of inspection for high pressure steam boiler?

6. What pressure is used for the hydrostatic test?

7. How often is the boiler blown down during the boiling out process?

8. Why must scale be removed from boiler tubes?

9. What is the purpose of handholes and manholes?

10. When inside the drums what do you look for?

REFERENCES

1. AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems.

2. AFR 91-7, Heating.

# BOILER LAY UP

## OBJECTIVE

Given study guide and workbook, answer questions about boiler lay up getting 80% of the questions correct.

## INTRODUCTION

Idle boilers can be protected from corrosion by boiler lay up. Idle boilers can be laid up by the dry storage or the wet storage method.

## INFORMATION

### DRY STORAGE

This method is preferred for prolonged outages (for more than 30 days) and freezing temperatures. Proceed as follows:

1. Thoroughly clean and dry unit, externally and internally. Place wooden trays of quicklime (2 pounds per 1000-gallon boiler capacity) inside the drums. In moist atmospheres, it is wise to place the trays in the furnace also. Silica gel (10 pounds per 1000-gallon boiler capacity) may be substituted for the quicklime to absorb moisture from the air. Fill trays only about 3/4 full. This will prevent overflow of liquid after moisture has been absorbed.

2. Tightly close all manholes, handholes, access doors, and observation doors. See that all connections to the boiler are tightly blanketed to prevent entrance of moisture from any source.

3. Inspect the unit monthly to be sure protection is effective.

4. Replace the absorbent material as required.

### WET STORAGE

This method is preferred for boilers which are in standby condition for short periods of time (not more than 30 days), and may be needed for service on short notice. Do not use it if freezing temperatures can be expected. Use the following procedure:

1. Close the boiler when it is clean and empty, and fill with water until it overflows through the drum vent, or through the superheater vent in superheater installations. While the boiler is being filled, continuously feed caustic soda and sodium sulfite into it. If this is not possible, use a circulating pump to uniformly distribute chemically treated water throughout the boiler.

2. Maintain boiler water concentration of 200-400 parts per million (PPM) of caustic soda and about 100-200 PPM of sodium sulfite.

3. After shutting off the overflow from the vent, maintain a water pressure in the boiler of 10 to 15 psig during storage.

4. Weekly, analyze water samples to find if required water concentration is maintained. If the alkalinity or sulfite has dropped below minimum limits, feed additional chemicals and circulate the boiler water to distribute it uniformly.

5. Before the boiler can be put back into service, the chemical dosage must be reduced to normal operating levels.

SUMMARY

We have studied the different ways to lay up an idle boiler. Preventing corrosion of idle boilers is a very important part of maintaining boilers used by the Air Force.

QUESTIONS

1. What is the purpose of boiler lay up?

2. What are the two methods of boiler lay up?

3. What chemicals are used in the wet method?

4. What is used in the dry method of boiler lay up?

5. What do the chemicals used in the dry method do?

REFERENCE

AFM 91-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems

# STEAM DISTRIBUTION SYSTEMS

## OBJECTIVES

Given information and with team member, maintain steam pressure using steam distribution system with instructor assistance.

Given study guide and workbook, answer questions about distribution system and conducts getting 80% of questions correct.

Given study guide and workbook, answer questions about installation and maintenance of converters getting 80% of questions correct.

Given procedures and with team member, perform maintenance on steam distribution system with instructor assistance.

Given procedures and with team member, replace insulation on steam distribution system with instructor assistance.

## INTRODUCTION

A heating specialist must know more than how to operate and maintain a boiler. Once he has generated the steam he must know what to do with it. He is also responsible for maintaining the steam system.

Each heating specialist should become thoroughly acquainted with every detail of the steam distribution system. He must know the purpose and location of the reducing stations, expansion joints, relief valves, strainers, steam consumers and traps.

We will begin our discussion with the different steam pressure ranges you will be using.

## INFORMATION

### PRESSURE RANGES

Steam heating systems are classified according to pipe arrangement, accessories used, method of returning the condensate to the boiler, method of expelling air from the system, or type of control employed. The successful operation of a steam heating system consists of generating steam in sufficient quantity to equalize building heat losses at a maximum efficiency, expelling entrapped air, and returning all condensate to the boiler rapidly.

Steam cannot enter a space filled with air or water at a pressure equal to the steam pressure. Therefore, it is important to eliminate air and to remove water from the distribution system.

Steam has different uses at different pressures:

- Low Pressure. Steam at pressures ranging from 0 to 15 psig is used for space heating, cooking, and distribution within small buildings.
- High Pressure Steam. Medium high pressure range (35 to 50 psig) is used for industrial, hangar, shop, and warehouse heating, sterilization, and cooking. High pressure steam greater than 50 psig is used for industrial purposes and outside distribution. Steam at 100 psig or higher is used for distribution systems with runs 2,000 feet or more in length. Figure 4-1 illustrates a schematic flow diagram of a steam distribution system. In this system, steam is generated at 100 psig in a central boiler plant and then distributed to different consumers. The diagram shows high pressure (100 psig) steam being converted to medium pressure (40 psig) steam for use in cooking and sterilizing equipment, also shows steam being reduced to low pressure (5 psig) steam for space heating. High pressure steam is used directly, without reduction, for some industrial laundry equipment.

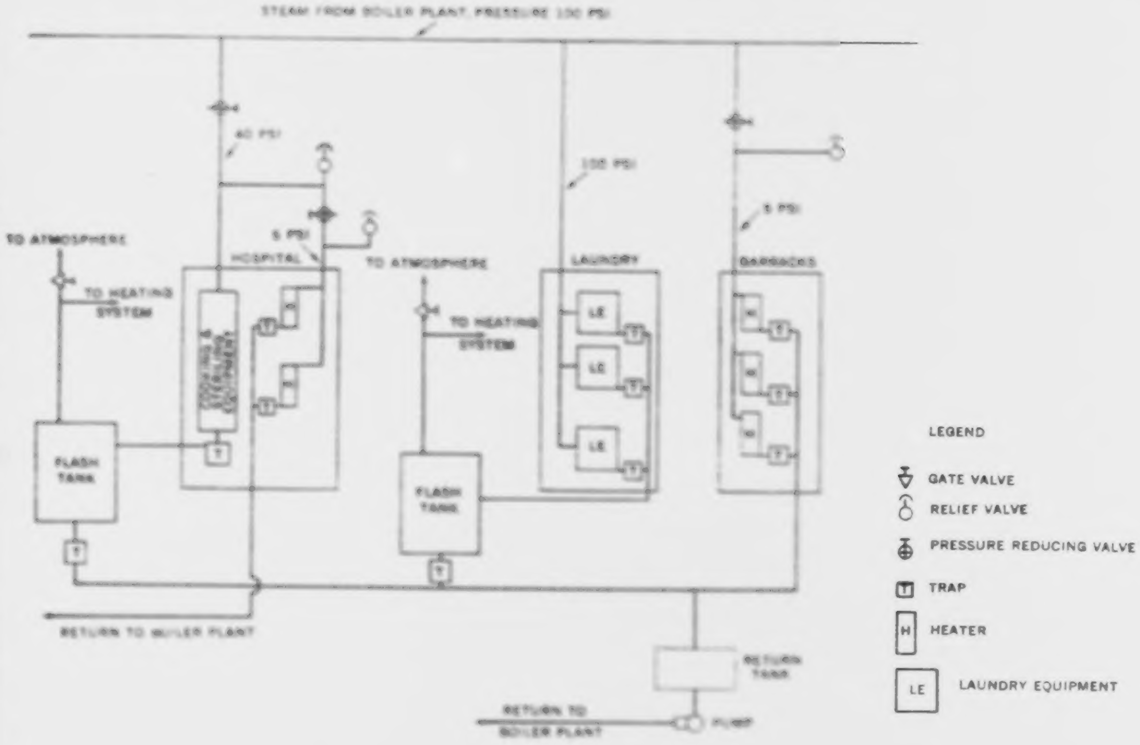
STEAM FROM BOILER PLANT, PRESSURE 100 PSI
40 PSI
100 PSI
5 PSI
5 PSI
TO ATMOSPHERE
TO HEATING SYSTEM
HOSPITAL
COOKING & STERILIZING EQUIPMENT
H
T
FLASH TANK
TO ATMOSPHERE
TO HEATING SYSTEM
LAUNDRY
LE
BARRACKS
FLASH TANK
RETURN TO BOILER PLANT
RETURN TANK
RETURN TO BOILER PLANT
PUMP
LEGEND
GATE VALVE
RELIEF VALVE
PRESSURE REDUCING VALVE
T
TRAP
H
HEATER
LE
LAUNDRY EQUIPMENT

Figure 1-1. Flow Diagram of a Steam Distribution System

Sources of Steam

Steam needed to heat a building or perform some mechanical work can be obtained from several sources, including the following:

CENTRAL HEATING PLANTS. For some purposes high-pressure steam from central heating plants can be used directly without pressure reduction.

PRESSURE REDUCING STATIONS. Pressure reducing stations are used when low or medium pressure steam is required, and a source of high pressure steam is available.

CONVERTERS. The use of converters as a source of steam will be discussed in a separate section.

LOW-PRESSURE HEATING STEAM BOILERS. A common source of low-pressure steam is the low-pressure heating steam boiler.

## DISTRIBUTION SYSTEMS

For purposes of this study guide, a steam distribution system consists of all the steam and return piping, related facilities, and equipment used to convey steam from a central steam generating plant to the consumers.

The subjects that will be covered will be as follows: pressure reducing stations, temperature regulating valve, expansion joints, types of distribution system conduits, converters, steam traps, condensate return systems, and insulation of steam distribution systems. A diagram of a steam distribution system is shown in Figure 4-1. Each subject will be covered in separate sections.

### Pressure Reducing Stations

When steam is drawn from a high-presure line to heat buildings or water, or for process work, reduce its pressure to the working pressure of the system with a pressure reducing station. A pressure reducing station may consist of pressure reducing valves, pressure regulating valve, relief valve, strainer and auxiliary valve.

### Pressure Reducing Valves

This is the first or primary valve of the pressure reducing station; its purpose is to reduce the steam pressure below the rupture-point of the equipment served. It can be either pilot-operated, spring-loaded or weight-and-lever operated.

WEIGHT-AND-LEVER. Figure 4-2 illustrates a weight-and-lever diaphragm-operated pressure-reducing valve. The low pressure side (controlled pressure) is connected below the diaphragm by an external balance line. The weight-and-lever operates best at pressures below 15 psi.

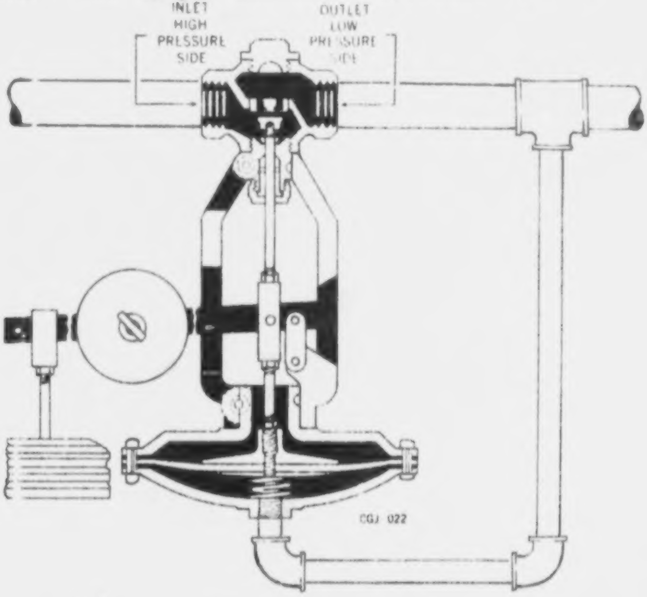

Figure 4-2. Weight-and-Lever Pressure Regulator

SPRING-LOADED. Figure 4-3 illustrates a diaphragm-operated spring-loaded pressure-reducing valve. The controller pressure is applied to the top chamber over the diaphragm and the diaphragm movement is directly transmitted to the control valve through the valve stem. In operation, an increase in the controlled pressure pushes the diaphragm against the resistance of the spring. This pressure closes the valve until the controlled pressure and the spring force are balanced. The controlled pressure can be adjusted by changing the spring compression.

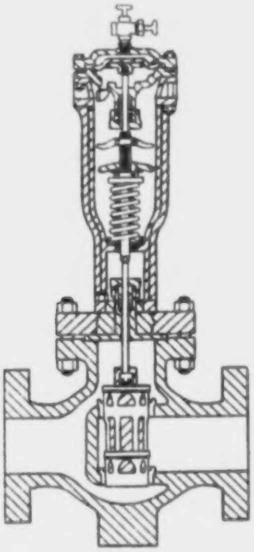

Figure 4-3. Spring-Loaded Pressure-Reducing Valve

PILOT-OPERATED. Figure 4-4 illustrates an internal pilot-operated valve with an operating piston. It functions as follows:

1. The valve discharge pressure acts on the bottom of the diphragm and pushes it up against the force exerted by the pressure regulating spring. The diaphragm finally assumes a position dependent upon these two forces.

2. A spring holds the pilot valve against the diaphragm; therefore, any movement of the diaphragm causes a corresponding movement of the pilot valve. One side of the pilot valve is connected to the supply pressure, the other side, to the top of the operating piston which is in permanent contact with the main valve.

3. A spring underneath the main valve holds it against the operating piston at all times, keeping the valve closed and the operating piston up. When the valve is in equilibrium, there is enough flow through it to keep the discharge pressure at the required level.

4. When pressure on the discharge side drops, a corresponding drop under the diaphragm allows the spring to force the diaphragm down and open the pilot valve. More fluid from the supply side then passes through the pilot valve, builds up pressure on top of the operating piston, and moves it down against the spring compression. This pressure opens the main valve, thereby increasing the flow and building up pressure in the discharge side until the valve is again in equilibrium. The procedure is reversed when the pressure on the discharge side increases.

5. To regulate the pressure on the discharge side, adjust the compression of the pressure-regulating spring.

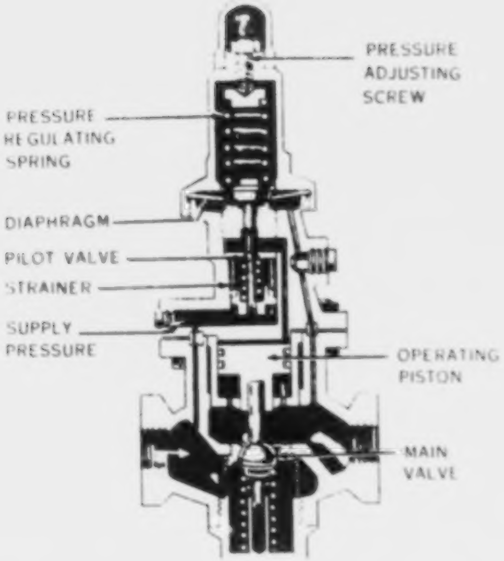

Figure 4-4. Pilot Operated Pressure Regulator

Pressure Regulating Valve

This is the secondary valve in a two-stage reducing station; it controls and maintains the optimum pressure required, by the steam consuming equipment. Pressure regulating valves are of the same types as reducing valves.

Safety Valve

This valve protects low pressure lines and steam consuming equipment from over pressure, if the pressure-reducing valve fails.

Strainer

Strainers are installed ahead of pressure reducing or pressure regulating valves to prevent the passage of loose dirt, rust, scale or other loose foreign material which would interfere with the proper operation of the equipment.

Auxiliary Valves

Install the isolating gate valves needed to remove pressure reducing and regulating valves from service. When a continuous supply of steam is required, and in large installations, install bypass valves around the pressure reducing and regulating valves. Use globe type bypass valves one-half the size of the pressure reducing or regulating valve to permit manual regulation.

Pressure Gauges

Bourdon tube steam gauges should be used before and after each pressure regulator valve.

Installation

When initial steam pressure is 100 psi or greater and the low pressure required is 5 psi or less, it is common practice to install two stage reduction. This type of installation reduces noise and cuts down wear on the valve seats, since large valve openings are possible. If one stage is desired, a pilot controlled single seat valve will usually prove satisfactory. If the pilot type cannot be used, two stage reduction is necessary since the plain diaphragm valve would require a diaphragm area which would be impractical.

In making a two stage reduction, allowance for increased volume of steam is made by increasing the pipe size of the low pressure side. Separating the two valves by a distance of up to 20 feet is recommended to reduce excessive hunting action of the first valve. Spring-loaded valves are usual if the reduced pressure is greater than 15 psi. Below this figure, the weight and level type gives good results.

Valves can be single seated, or balanced. Single seated valves are used for dead-end service, where pressure must be maintained during no-flow period. This type of valve can be closed tightly. Balanced valves require smaller forces to operate, because the pressure acts on both sides of the disk. They do not close tightly.

In duplex installations, two valves of different sizes are installed in parallel positions. They are adjusted to permit the smaller valve to handle the entire flow until its capacity is exceeded; then, the large valve opens. Duplex installations are used when wide variations in flow requirements are expected. In these cases, it is not practicable to use only valves large enough to handle the maximum flow, because low-flow operation would require only a very slight movement of the valve and wiredrawing, wearing, and valve-seat cutting would occur.

## TEMPERATURE REGULATING VALVES

Temperature regulating valves (figure 4-5) consist basically of three elements: a temperature sensing device (temperature bulb), a regulating valve actuated by a bellows to control the passage of the fluid, and capillary tubing to connect the temperature bulb with the bellows. In operation, temperature changes at the bulb produce expansion or contraction of the medium which fill the system. These, in turn, cause expansion or contraction of the bellows, actuate the valve, and move the valve stem. The expansion movement of the bellows is opposed by an adjustable compression spring or a weighted lever area. The controlled temperature can be adjusted by changing the compression of the spring or the position of the lever weight.

### Operational Preventive Maintenance

Only authorized and trained personnel should repair, calibrate, or adjust temperature controls. When steam flow is controlled by temperature controls, slowly warm up the line and drain the condensate before operating the regulating valve. Blow down strainers and clean the baskets at regular intervals and whenever necessary.

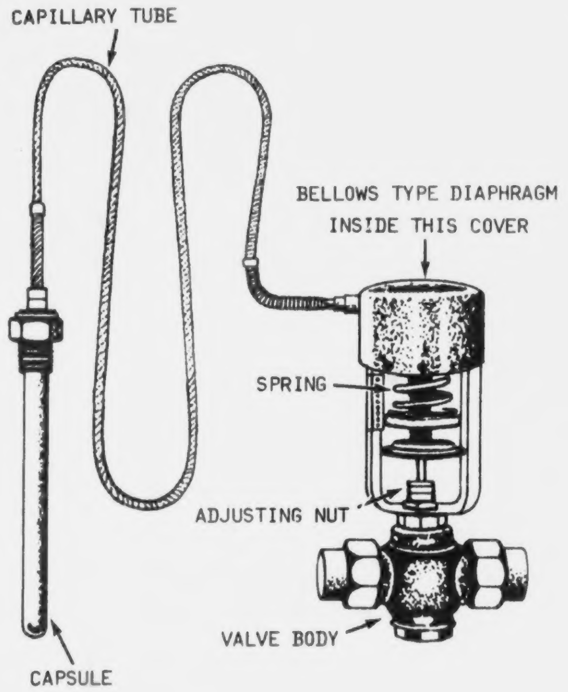

Figure 4-5. A Temperature-Regulating Valve

Preventive Maintenance Inspections

DAILY. Observe operation of the control for proper functioning. Check leaks. Stop stuffing-box leaks as soon as possible.

YEARLY. Once a year, or more often if required, dismantle valve and control mechanism, clean components and inspect for wear, corrosion, erosion, pitting, deposits, leaks or other defects. Check settings, adjustment, and control operation.

## EXPANSION JOINTS

Because of limitations of the supports, or the space or extra length of pipe required, it is sometimes inconvenient to compensate for expansion of a line with the special bends and loops made for this purpose. As an alternative, expansion joints may be used. The number of expansion joints installed in a line depends on the amount and direction of expansion and the amount of expansion permitted by each joint. Table 1 gives expansion per 100 feet for pipe of various types and at various temperatures.

TABLE 1. EXPANSION OF PIPE PER 100 FEET OF LENGTH FOR TEMPERATURE SHOWN

| Temperature Degrees F | Material | | |
|---|---|---|---|
| | Steel | Wrought Iron | Copper |
| 0 | 0 | 0 | 0 |
| 10 | 0.075 | 0.078 | 0.111 |
| 20 | 0.149 | 0.156 | 0.222 |
| 30 | 0.224 | 0.235 | 0.333 |
| 40 | 0.299 | 0.313 | 0.444 |
| 50 | 0.374 | 0.391 | 0.556 |
| 60 | 0.449 | 0.470 | 0.668 |
| 70 | 0.525 | 0.549 | 0.780 |
| 80 | 0.601 | 0.629 | 0.893 |
| 90 | 0.678 | 0.709 | 1.006 |
| 100 | 0.755 | 0.791 | 1.119 |
| 110 | 0.831 | 0.871 | 1.233 |
| 120 | 0.909 | 0.952 | 1.346 |
| 130 | 0.987 | 1.003 | 1.460 |
| 140 | 1.066 | 1.115 | 1.575 |
| 150 | 1.145 | 1.198 | 1.690 |
| 160 | 1.224 | 1.281 | 1.805 |
| 170 | 1.304 | 1.364 | 1.919 |
| 180 | 1.384 | 1.447 | 2.035 |
| 190 | 1.464 | 1.532 | 2.152 |
| 200 | 1.545 | 1.616 | 2.268 |
| 210 | 1.626 | 1.701 | 2.384 |
| 220 | 1.708 | 1.786 | 2.501 |
| 230 | 1.791 | 1.871 | 2.618 |
| 240 | 1.872 | 1.957 | 2.736 |
| 250 | 1.955 | 2.044 | 2.854 |
| 260 | 2.038 | 2.130 | 2.971 |
| 270 | 2.132 | 2.218 | 3.089 |
| 280 | 2.207 | 2.305 | 3.208 |
| 290 | 2.291 | 2.393 | 3.327 |

TABLE 1. EXPANSION OF PIPE PER 100 FEET OF LENGTH FOR TEMPERATURE SHOWN (Cont)

| Temperature Degrees F | Material | | |
|---|---|---|---|
| | Steel | Wrought Iron | Copper |
| 300 | 2.376 | 2.481 | 3.446 |
| 310 | 2.460 | 2.570 | 3.565 |
| 320 | 2.547 | 2.659 | 3.685 |
| 330 | 2.632 | 2.748 | 3.805 |
| 340 | 2.718 | 2.838 | 3.926 |
| 350 | 2.805 | 2.927 | 4.050 |
| 360 | 2.892 | 3.017 | 4.167 |
| 370 | 2.980 | 3.108 | 4.289 |
| 380 | 3.069 | 3.199 | 4.411 |
| 390 | 3.156 | 3.291 | 4.532 |
| 400 | 3.245 | 3.383 | 4.653 |
| 410 | 3.334 | 3.476 | 4.777 |
| 420 | 3.423 | 3.569 | 4.899 |
| 430 | 3.513 | 3.662 | 5.023 |
| 440 | 3.603 | 3.756 | 5.145 |
| 450 | 3.695 | 3.850 | 5.269 |
| 460 | 3.785 | 3.945 | 5.394 |
| 470 | 3.874 | 4.040 | 5.519 |
| 480 | 3.962 | 4.135 | 5.643 |
| 490 | 4.055 | 4.231 | 5.767 |
| 500 | 4.148 | 4.327 | 5.892 |

### Slip Type Expansion Joint

The slip type expansion joint consists of an outer casing or body which is anchored, a sliding tube which fits into the body, and a means of preventing leakage between the inner and outer sections. An example of this type of joint is shown in figure 4-6. This is an example of a double joint in which a plastic type of packing is used. The plunger (figure 4-7) is backed out, packing is forced in with a pressure gun similar to that used for greasing automobiles, and the plungers are then screwed down. This joint may be applied with welded or flanged construction. Several types of similar joints use ordinary braid packing adjusted by means of a gland. They may be either the outside guided type or inside guided joints. The pipeline must be held in alignment if this type of joint is to function properly. Expansion or contraction moves the inner sleeve in the main anchored casing or body. Stops must be provided in these joints to prevent their pulling apart.

Slip type joints must be kept properly aligned, adequately packed, within the proper limit of travel, and thoroughly cleaned and lubricated. Adjust or replace packing, as required, to prevent leaks and assure a free working joint. Lubricate every six months, using the proper grease for the type of joint and service conditions. Once a year, check the flange-to-flange distance of slip joints, first when cold and then when hot, to make sure that travel is within the limits shown in the manufacturer's data. A change in slip travel usually indicates a shift in anchorage or pipe guide. Locate and correct the difficulty. Also inspect annually for signs of erosion, corrosion, wear, deposits, and binding. Repair or replace defective parts as required.

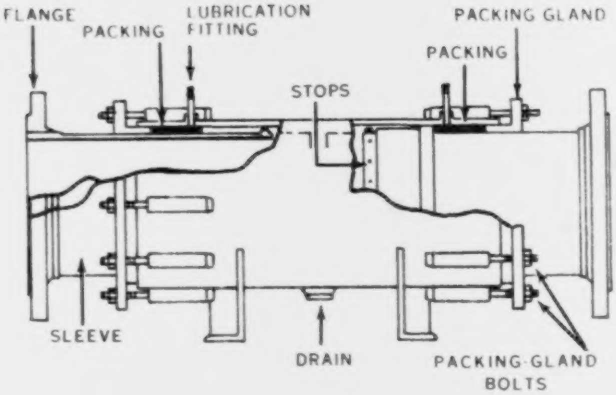
FLANGE
PACKING
LUBRICATION FITTING
PACKING GLAND
PACKING
STOPS
SLEEVE
DRAIN
PACKING-GLAND BOLTS

Figure 4-6. Slip Type Expansion Joint

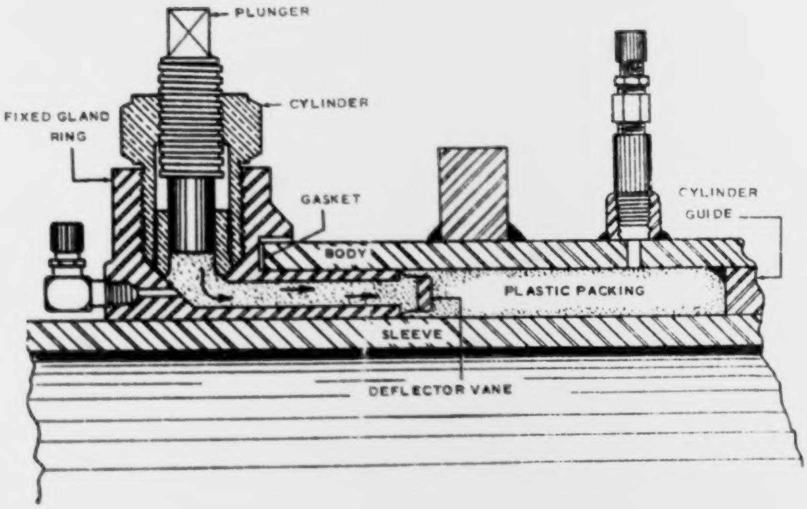
PLUNGER
CYLINDER
FIXED GLAND RING
GASKET
CYLINDER GUIDE
BODY
PLASTIC PACKING
SLEEVE
DEFLECTOR VANE

Figure 4-7. Slip Type Expansion Joint with Plastic Packing

The expansion in the bellows type of joint is taken care of by the flexing of a metal bellows. When installed in the line, the joint consists of a corrugated thin-walled copper tube which is clamped between the flanges (see figure 4-8). The rings help to keep the corrugations in the joint under high pressures. This joint does not usually have a safety stop. Another type of joint (see figure 4-9) uses a stainless steel multidisk bellows. This joint has an internal sleeve which acts as a stop to limit the flexing of the disks and to limit the maximum flow of steam through the bellows if the disks rupture. Both these joints can compensate for a small amount of misalignment, but the pipe should be supported and guided in such a way that misalignment is reduced to a minimum. It is best that misalignment be prevented altogether if possible.

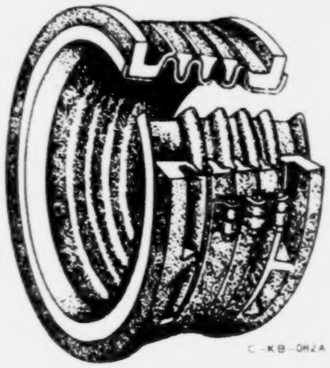

Figure 4-8. Corrugated Bellows Type Expansion Valve

Annually, check bellows joints for misalignment, fatigue, corrosion, and erosion, note the amount of travel between cold and hot conditions. If the joint fails, replace the bellows section.

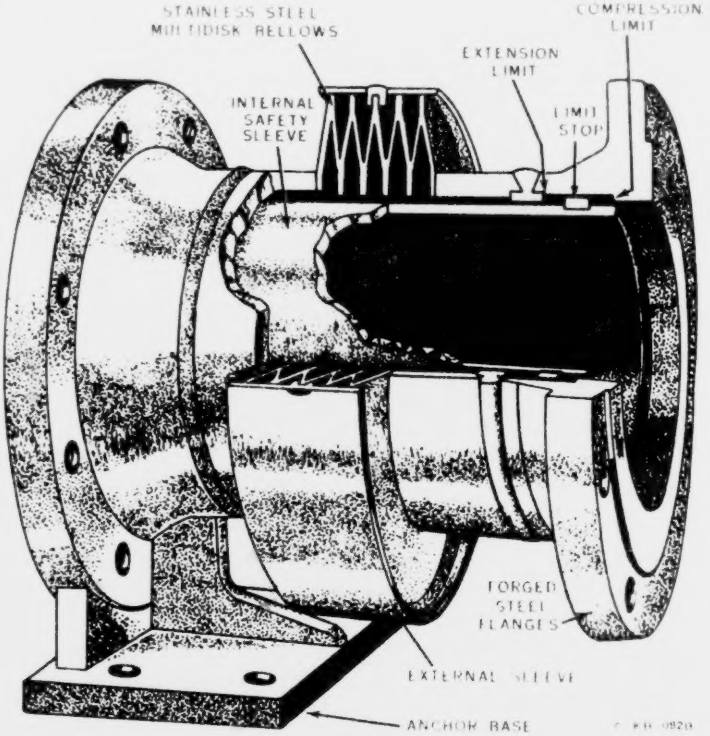
STAINLESS STEEL
MULTIDISK BELLOWS
COMPRESSION
LIMIT
EXTENSION
LIMIT
INTERNAL
SAFETY
SLEEVE
LIMIT
STOP
FORGED
STEEL
FLANGES
EXTERNAL SLEEVE
ANCHOR BASE

Figure 4-9. Multidisk Bellows Type Expansion Valve

### Expansion Loops

The expansion loop offers the best means for absorbing pipeline expansion because it requires no maintenance and will last as long as the pipe line. However, it is not always the most economical means of absorbing expansion, so that its use must be weighed against other types of expansion joints.

### Types of Exterior Steam Distribution Systems

The exterior distribution system is divided into underground and aboveground systems.

UNDERGROUND SYSTEMS. The major underground systems are the conduit and the utilidor types of systems. These systems are normally installed only in permanent heating installations because of their high cost of installation.

Conduit Type. In the conduit type of steam distribution system, the pipe is installed inside a conduit that is buried below the frostline. The frostline is the lowest depth that the ground freezes during the coldest part of winter. The pipe used for steam is black steel pipe.

The conduit and insulation serve to protect and insulate the steam pipe. One type of conduit is illustrated in figure 4-10. The conduit must be strong enough to withstand the pressure of the earth and the usual additional loads that are imposed upon it.

Several types of materials and various designs are used in the manufacture of conduit. Common types of conduit are constructed of masonry cement, galvanized iron, and steel. The conduit is usually sealed with asphaltic tar or some other type of sealer to prevent water from getting into the insulation and deteriorating it. Insulation may be attached directly to the pipe, attached to the inner surface of the conduit, or in loose form and packed between the pipe and the conduit.

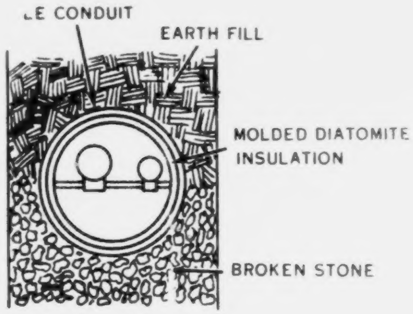

Figure 4-10. A Steam Distribution Conduit

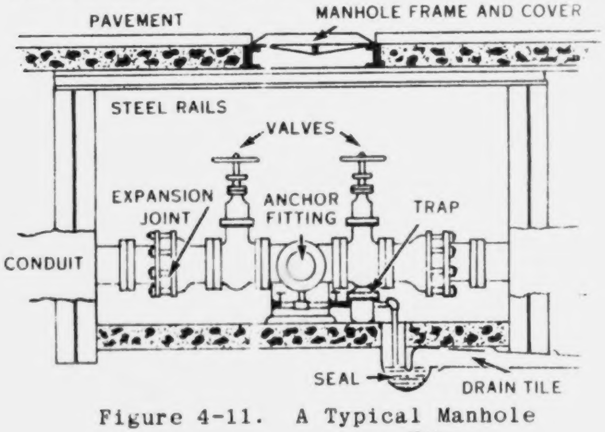

Figure 4-11. A Typical Manhole

The bottom of the trench for the conduit should be filled with coarse gravel or broken rock to provide support and adequate water drainage. When allowed to collect, the water seeps into the conduit through porous openings in the sealer. This wets the insulation and causes it to lose much of its insulating value. Manholes are required at intervals along the line to house the necessary valves, traps, and expansion joints. A typical manhole is illustrated in figure 4-11.

Utilidor Type. The utilidors or tunnels of the utilidor type of system are constructed of rock or concrete. The size and shape of the utilidor usually depends upon the number of distribution pipes to be accommodated and the depth the utilidor must go into the ground. Manholes, sometimes doors, are installed to provide access to the utilidor (tunnel). A typical utilidor is shown in figure 4-12. The utilidor is usually constructed so that the steam and condensate return lines can be laid along one side of the tunnel on pipe hangers or anchors. This is usually done with the type of pipe hanger with rollers that provide for the free movement required by the expansion of the pipe that occurs. The other side of the utilidor should be a walkway that provides easy access to lines when you are inspecting and doing maintenance.

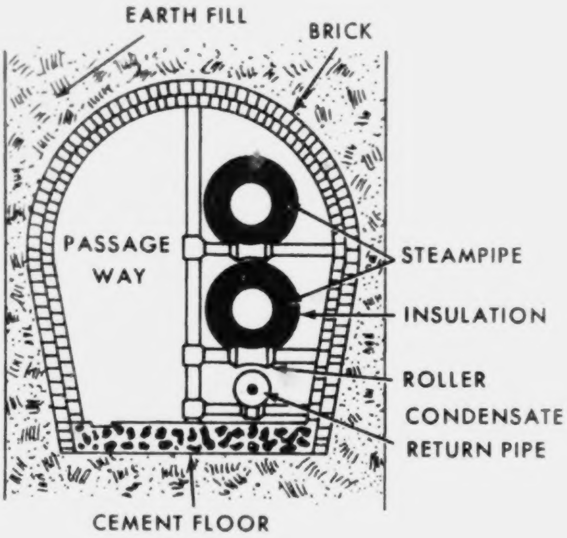

Figure 4-12. A Typical Utilidor

ABOVEGROUND SYSTEMS. Aboveground steam distribution systems are further divided into overhead and surface systems.

Overhead Distribution Systems. Overhead distribution systems are often used in temporary installations, however, they are sometimes used in permanent installations. The main drawback to this type of distribution system is the high cost of maintenance. The overhead system is similar in many respects to the underground distribution system. They require valves, traps, provision for pipe expansion, and insulated pipes. The main difference is that the steam distribution and condensate return piping are supported on pipe hangers from poles, as illustrated in figure 4-13 instead of being buried underground.

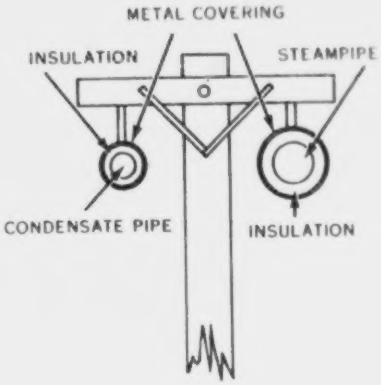

Figure 4-13. Overhead Steam Distribution System

Surface. In some cases, you will find that steam and condensate lines are laid in a conduit along the surface of the ground. These systems, however, are not as common as overhead and underground systems. Surface systems require about the same components as the overhead and the underground systems--traps, valves, pipe hangers to hold the pipes in place, and provision for pipe expansion. Sometimes an expansion loop, formed by a loop of pipe, is used instead of an expansion joint to provide for pipe expansion.

MAINTENANCE. The maintenance required for exterior distribution systems normally consist of inspecting, repairing, and replacing insulation, traps, valves, pipe hangers, expansion joints, conduit, utilidors, and aluminum or galvanized metal coverings used on aboveground distribution systems. The maintenance required on conduit and utilidors consists of keeping the materials of which they are constructed from being damaged and of insuring that water is kept out of the tunnels and pipes. The maintenance required on outside metal coverings is about the same as that for the conduit and utilidors.

### Inspection of Manholes

Clean and inspect manholes quarterly (every 3 months). Check roof slab, frame and cover, walls and floor for deterioration. Check manhole drain, sump pit and sewer connection. Inspect ladders, make sure that vents are unobstructed, check condition of conduit seals, telltales, and drain plugs.

Water-tightness is an important requirement in manholes. Water is the biggest problem with the maintaining of the manholes, as corrosion will be set up very quickly if water is allowed to enter the manhole.

## INSTALLATION AND MAINTENANCE OF CONVERTERS

### General

A converter is a shell-and-tube heat exchanger which transfers heat from steam (or HTW) to water. The heated water is used as the heating medium for a hot water system. The converter shell (of cast iron or steel) must be thick enough and the tubes (of admirality metal, copper nickel, or copper) adequate to carry the required pressures.

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Tubes or coils are usually installed in a horizontal, multipass arrangement that gives an equal flow velocity through all the tubes. However, care must be taken to prevent bypassing or short-circulating the hot water, or stratifying the steam or HTW. Normally, flanged openings permit easy removal of tubes for cleaning and repair.

In steam converters, the shell or tank holds the steam and the water to be heated flows through the tubes. In HTW converters, the HTW usually flows through the tubes and the water to be heated remains in the shell or tank.

### Accessories

Converters usually have the following accessories:

(1) Inlet and outlet connections for both primary and secondary mediums.

(2) Adequate opening in the shell for the control element.

(3) Drain valve for the shell.

(4) Relief valve (pressure or temperature actuated).

(5) Thermometer.

### Applications

Either HTW or steam can be used as the heating medium. When steam is used, condensate is removed through a trap, and discharged to a condensate return system, a hot well, a flash tank or such. The least desirable arrangment is to discharge the condensate to a sewer.

## TRAPS AND STRAINERS

Steam traps are automatic devices which perform the following functions: Drain condensate, remove air and other noncondensable gases, prevent the escape of uncondensed steam through drain lines.

Traps have the following parts: A vessel where the condensate accumulates; an orifice through which the condensate discharges, a valve to close the orifice port; mechanisms to operate the valve, and inlet and outlet openings through which condensate enters and leaves the trap vessel. Steam traps are classified according to operating device.

### Thermostatic Trap

Figure 4-14 illustrates a thermostatic trap operated by the expansion or contraction of bellows which are activated by temperature changes. The chamber inside the bellows is filled with a liquid or contains a small amount of volatile liquid, such as alcohol. The liquid expands or becomes a gas then steam contacts the expansive element. The resultant pressure expands the element and closes the valve, preventing the escape of steam. When condensate or air contacts the element, it cools and contracts, thereby opening the valve and permitting the condensate and air to escape. The discharge from this type of trap is intermittent. Some thermostatic traps have metal diaphragms which function in the same manner as the bellows. Thermostatic traps are widely used on radiators and convectors.

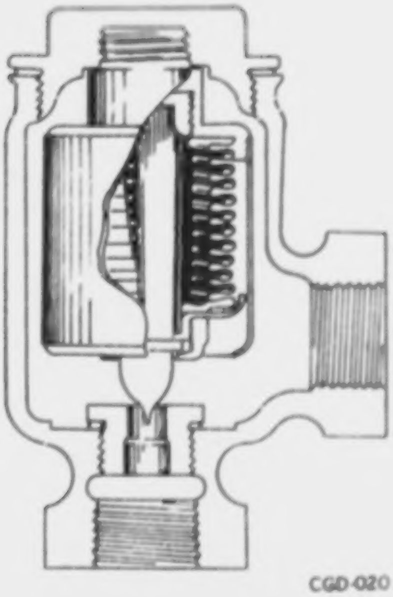

Figure 4-14. Thermostatic Trap

## Float and Thermostatic Trap

A combination float and thermostatic trap (figure 4-15). The thermostatic trap normally vents the air, but it can also discharge water if the capacity of the float valve is exceeded. Water enters the trap and rises the float, carrying the vertical valve with it. This action opens the valve and permits the water to discharge, as the water level in the chamber drops, the float gradually drops and closes the valve. Normally, with a constant flow of condensate to the trap, the level of water in the trap is stable and the trap discharges water continuously at the same rate as the condensate enters. At low rates of flow the level of water in the trap is low and throttling of the discharge causes the seats to cut badly, a disadvantage characteristic of this type of trap. The thermostatic trap in the top of the chamber remains closed as long as there is steam around it. This trap can be opened for inspection or repair without disturbing any pipe connections.

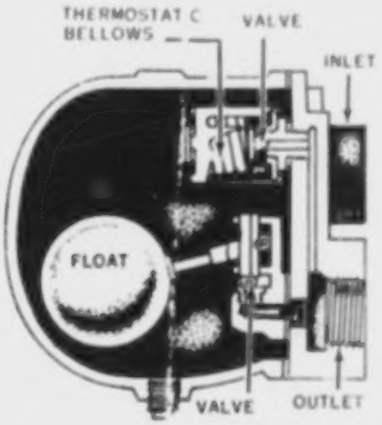

Figure 4-15. Float and Thermostatic Trap

### Bucket Trap (Upright)

Figures 4-16a, 4-16b, 4-16c, illustrate the three phases of upright-bucket trap operation. In this type of trap, the condensate enters the trap chamber and fills the space between the trap bucket and walls. When this happens the bucket floats and closes the valve. When the condensate level rises above its edge, the bucket fills and sinks, withdrawing the valve from the seat. Then the steam pressure, acting on the condensate in the bucket, forces the water through the discharge opening. When the bucket is empty, it rises and closes the valve. Then another cycle begins.

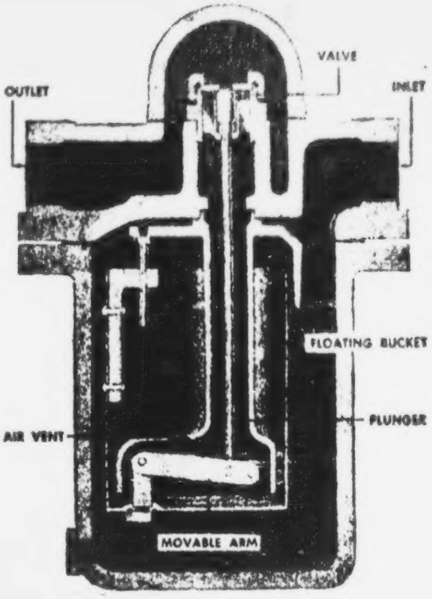

Figure 4-16a. Bucket Trap with Trap Closed

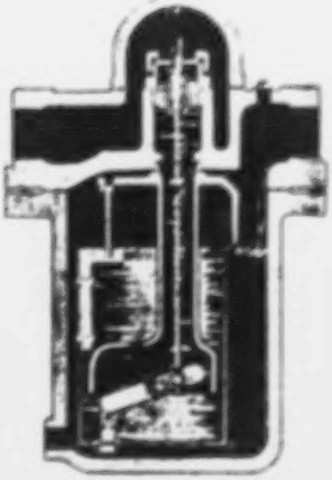

Figure 4-16b. Bucket Trap Discharging Water

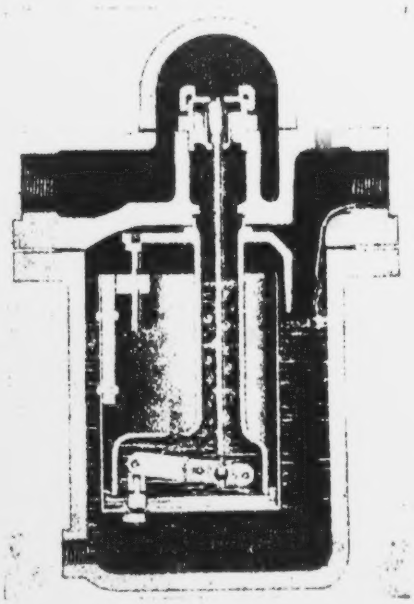

Figure 4-16c. Bucket Trap After Discharging Water

Figures 4-17 and 4-18 show how the inverted bucket trap operates. In this type of trap, steam, condensate, and air enter under the bell of inverted bucket. The steam floats in the bucket and closes the valve. The air escapes through a small vent in top of the inverted bucket. As condensate enters the trap, the bucket falls and opens the valve. The condensate discharges through the open valve until steam again enters and displaces the water in the bucket causing it to rise and close the valve. These traps are suitable for draining condensate from steam lines or other equipment where abnormal amounts of air must be discharged.

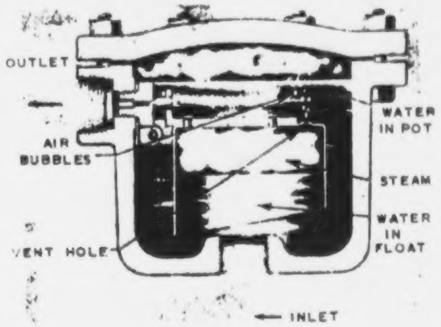

Figure 4-17. Inverted Bucket Trap With Trap Closed

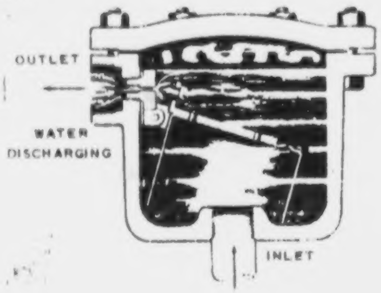

Figure 4-18. Inverted Bucket Trap Discharging Water

Impulse Trap

In the impulse trap, illustrated by figure 4-19 the flashing action produced by a pressure drop in the hot condensate govern the movement of a valve by changing the pressure in a control chamber above the valve. In operation, condensate builds up pressure below the control disk, lifting the valve like a piston. Air and condensate discharge, and a small portion of the flow (control flow) moves up around the disk to the lower pressure-control chamber. The pressure in this chamber remains low while the control flow discharges, through the orifice in the valve body, to the trap outlet side. When condensate reaches near-steam temperature, the reduced pressure in the control chamber causes part of the control flow to flash into steam. The increased volume in the control chamber chokes off some of the flow through the control orifice to build up pressure in the chamber. The valve closes and shuts off all discharge except the small amount flowing through the control orifice. Impulse traps can be used to drain condensate from steam mains, unit heaters, laundry equipment, sterilizers, and other equipment in which pressure at the trap outlet is 25 percent or less than inlet pressure.

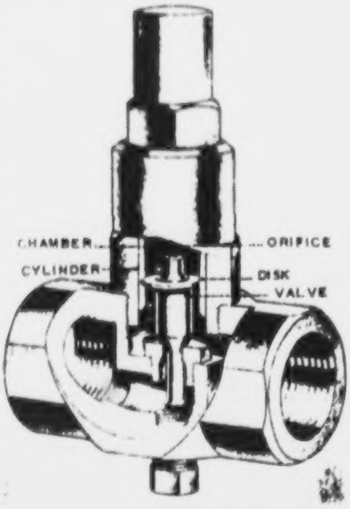

Figure 4-19. Impulse Trap

Bimetallic Trap

This trap operates by the bending of a bimetallic strip. This bimetallic element bends back and forth as condensate or steam comes to the trap. As condensate cooler than the steam comes to the trap, the element bends one way opening the valve. When hot steam comes along the element bends the opposite way, closing the valve.

The bimetal element is somewhat similar to the element that operates the ordinary thermostat except that it is of heavier construction. In one form of trap the bimetal element is made of a number of laminations in order to increase the force available to open and close the valve. (See figure 4-20).

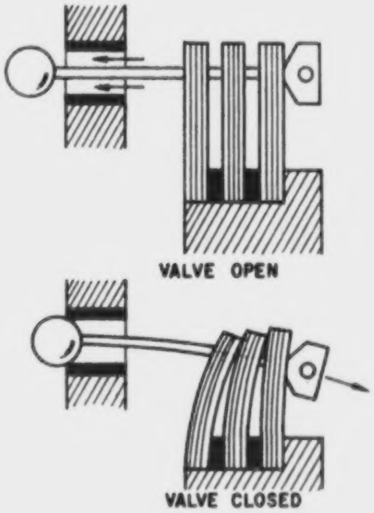

Figure 4-20. Bimetal Element

Thermodynamic Trap

The thermodynamic steam trap has only one moving part, a disc that covers the discharge port and operates as a valve to control the exit of air and condensate from the trap. Condensate and/or pressure lifts the disc off the discharge port seat and steam pressure forces the condensate and air through the discharge port.

Discharge continues until flashing condensate approaches steam temperature when high velocity jets of flash steam move rapidly across the underside of the disc to reduce the pressure underneath the disc. Meanwhile the steam builds up pressure in the control chamber above the disc and forces the disc against its seat, thus closing the trap.

Installation and Maintenance

Application of the following procedures will enhance steam trap operation.

PRIMING. Bucket traps require priming. Before starting operation, remove the test plug on top of the trap and fill it with water. Traps can also be primed by opening the steam supply valve slowly and keeping the trap discharge closed until it is filled with condensate.

INSULATION. Keep insulation in good condition at all times. If heat conservation is a major item, insulate traps that are in continuous use. One exception to this is the thermostatic trap which depends on the cooling effect of the condensate for operation.

BY-PASS VALVES. These valves are used during start-up to accelerate the discharge of condensate and air. Keep them closed during normal operation. By-passes are sometimes installed to permit maintenance of traps and strainers without shutting off steam.

BLOW DOWN. Blow down steam traps periodically to get rid of dirt accumulations. Do not remove thermostatic elements while they are hot, or they may expand beyond the stroke range of the bellows or diaphragm.

AIR VENTS. Open the air vents on float traps periodically to vent out accumulated air.

TRAP TESTING. Traps can be tested without breaking the installation by opening test valve and closing discharge valve. Intermittent discharge dribble, or semi-continuous discharge indicate correct operation. A continuous steam blow indicates defective valve, loss of prime, or foreign matter on valve seat. A continuous condensate flow indicates that the trap is too small, the amount of condensate drained abnormally high, or the trap inlet pressure abnormally low.

REPAIRS. Once a year, or more often if required, completely dismantle and clean all steam traps. Inspect for the following: plugging of orifices and vents, corroded, eroded, worn out, or otherwise defective parts; wear, grooving, and wire-drawing of valves and seats; defective bellows, buckets or floats. Replace or repair parts as required. Use only matched sets of replacement valves and seats. Do not change the weight of floats or buckets when repairing traps, or operation may be affected. After repairing a trap it should be checked using a steam trap testing rack.

## CONDENSATE RETURN SYSTEMS

The steam and condensate lines on steam distribution systems usually run in separate conduits. Condensate pumps normally return the condensate from each building or group of buildings to the central heating plant. When site contour and boiler plant location in relation to the buildings served are favorable, condensate can sometimes be returned by gravity.

When condensate is returned to the central heating plant, heat is saved, and boiler makeup water and water-treatment equipment requirements and treatment costs are reduced. Condensate from pickling tanks, electroplating baths, degreasing equipment, opensteam cookers, and other sources likely to produce contamination's discharge it to waste.

## Gravity Return System

In gravity return systems, the condensate returns to the boiler under its own hydraulic head. Heating units must be sufficiently elevated above the boiler water line to overcome the pressure drops caused by flow and the pressure differentials due to operation. Figure 4-21 illustrates a typical gravity return system for a small building.

HARTFORD LOOP. (Figure 4-21) The sole function of the Hartford loop is to prevent loss of boiler water through backward flow into the return mains. The upper portion of the loop is attached by a close nipple to the equalizer connection between the boiler supply header and the return yoke. The nipple connection is placed so that the water level in the boiler cannot be lowered more than from 2 (for gravity-return systems) to 4 (for pump-return systems) inches below the normal water line.

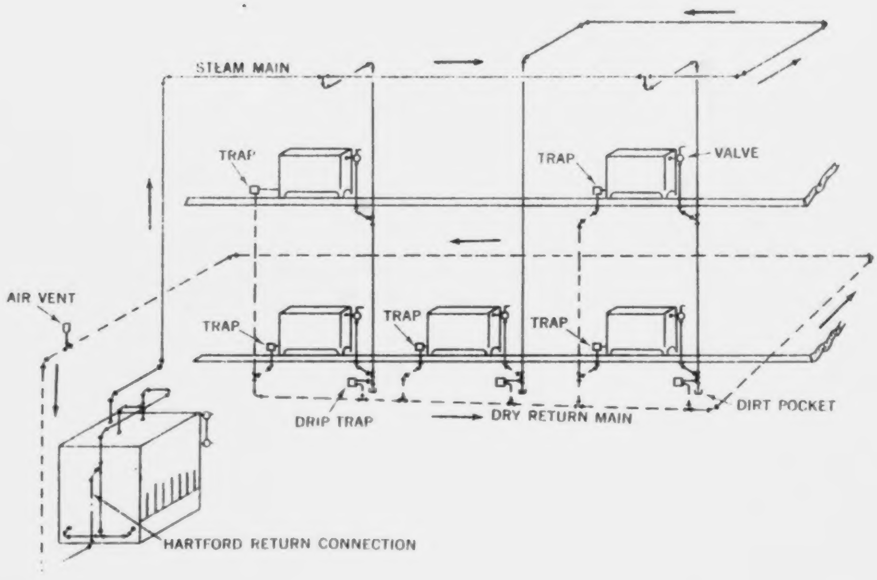

Figure 4-21. Typical Down-Feed Two-Pipe Gravity System

## Mechanical Return of Condensate

In gravity returns systems, all heating units must be located high enough above the boiler waterline to produce a gravity flow of condensate toward the boiler. Many times this condition cannot be met, and condensate must be returned by mechanical means. Two methods for mechanically returned condensate are used; alternating return trap systems and pumped returned systems.

ALTERNATING RETURN TRAP SYSTEM. Figure 4-22 illustrates a two-pipe, vapor, alternating return trap system. This system, as its name indicates, alternately fills and dumps. It returns condensate to the boiler by a mechanical, alternating return trap instead of gravity. The alternating return trap consists of a vessel with a float which, by linkages, controls two valves simultaneously so that one is closed when the other is open. One valve opens to the atmosphere; the other is connected to the steam header. The bottom of the vessel is connected to the wet return. In operation, when the float is down, the valve connected to the steam header is closed and the other is open. As condensate returns, it goes through the first check valve and rises into the return trap, which is normally located 18 inches above the boiler waterline. The float starts to rise and, when the water reaches a certain level in the trap, the air vent closes and the steam valve opens. This equalizes trap and boiler pressures, permitting the water flow by gravity from the trap, through the boiler check valve, into the boiler. The float then returns the trap to the normal vented position, ready for the next flow of return water.

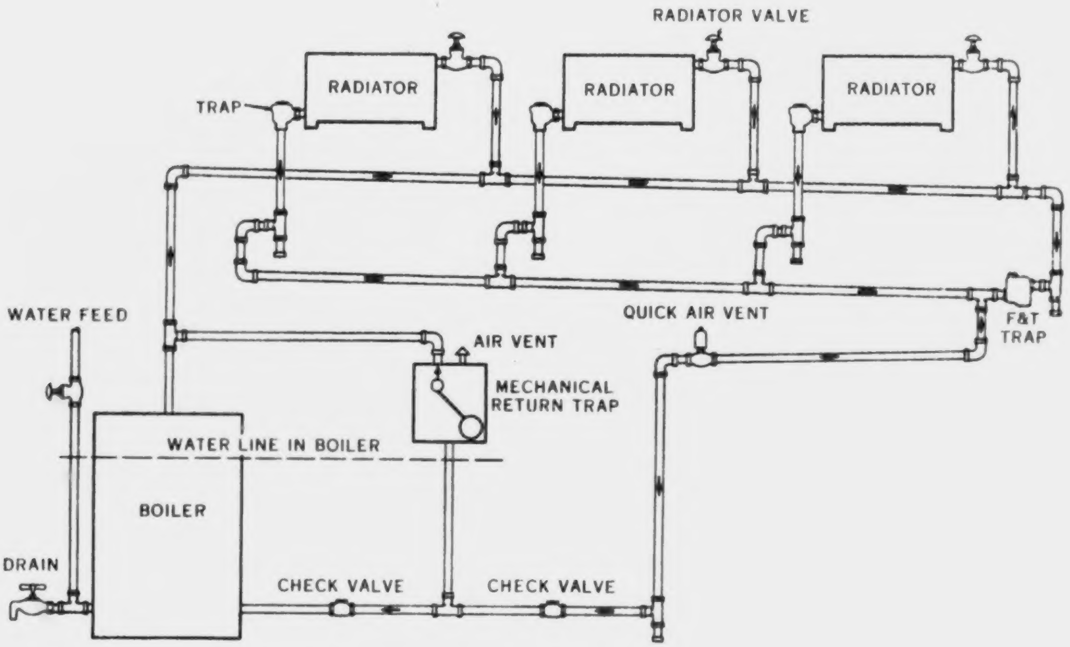
RADIATOR VALVE
RADIATOR
RADIATOR
RADIATOR
TRAP
WATER FEED
QUICK AIR VENT
AIR VENT
F&T TRAP
MECHANICAL RETURN TRAP
WATER LINE IN BOILER
BOILER
DRAIN
CHECK VALVE
CHECK VALVE

Figure 4-22. Two-Pipe Vapor Alternating Return Trap Systems

PUMPED-RETURN SYSTEM. There are two types of pumped-return systems: the condensate and the vacuum. In both, it is important to obtain gravity flow of the condensate to the pump inlet or to an auxiliary receiver, so the pump can force the water back to the boiler by raising the condensate pressure to the proper level.

Condensate Pump-Return System. (Figure 4-23). In this system, a centrifugal pump forces the condensate to the boiler under atmospheric or higher pressure.

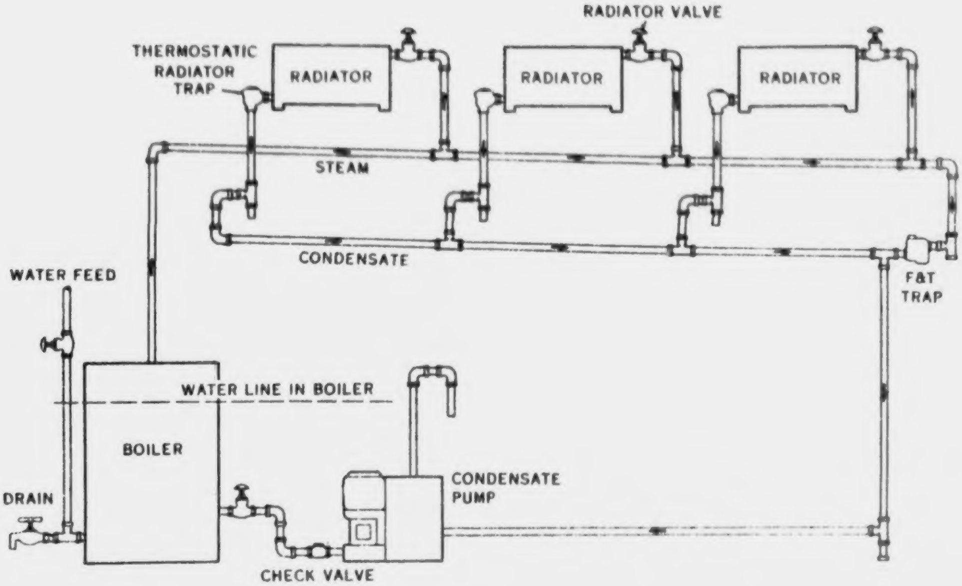
RADIATOR VALVE
THERMOSTATIC RADIATOR TRAP
RADIATOR
RADIATOR
RADIATOR
STEAM
CONDENSATE
WATER FEED
F&T TRAP
WATER LINE IN BOILER
BOILER
DRAIN
CONDENSATE PUMP
CHECK VALVE

Figure 4-23. Two-Piped Condensate Pump Return System

Figure 4-24 illustrates a typical condensate pumping unit, consisting of pump, motor, receiver, and float control. The pump operates intermittently under the action of the float-controlled switch.

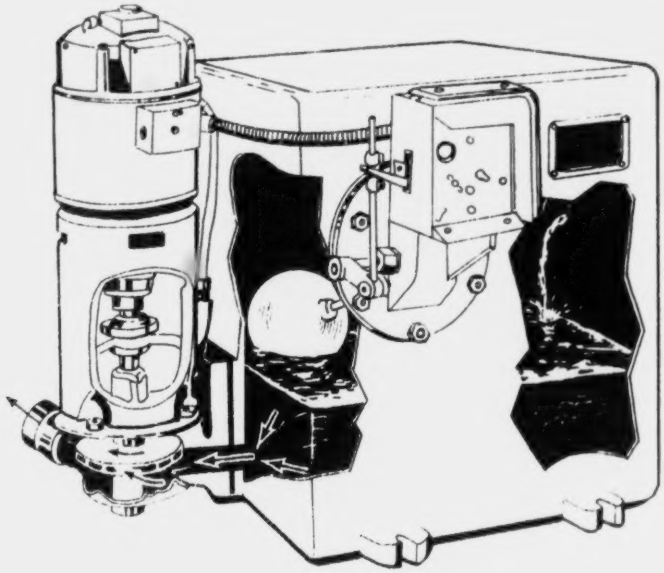

Figure 4-24. Condensate Pumping Unit

VACUUM PUMP RETURN SYSTEM. In this system a vacuum pump creates a vacuum in the return piping. Figure 4-25 illustrates a two-pipe vacuum system. The return outlet of each heating unit in this system is fitted with a thermostatic trap which allows both air and condensate to pass but closes against flow. This system may operate with low pressures in the supply main, but it can also maintain a vacuum in the return piping for all operating conditions. If a vacuum of 3 to 10 inches is kept in the return system, heating units can fill very rapidly at low steam pressures (0 to 20 psig), since air removal does not depend on steam pressures.

The vacuum pump performs the following functions: Withdraws air and water from the system, separates air from water, vents air to the atmosphere, and pumps condensate back to the boiler, feedwater heater, or hot well. Usually the pump has both a float switch and vacuum switch. In this type of system, be sure that all connections from the supply to the return side are made through a trap. Condensate temperature conversely affects the vacuum maintained, the higher the temperature, the lower the possible vacuum. Steam leaks from the supply to the return side will increase the condensate temperature and thereby decrease the vacuum.

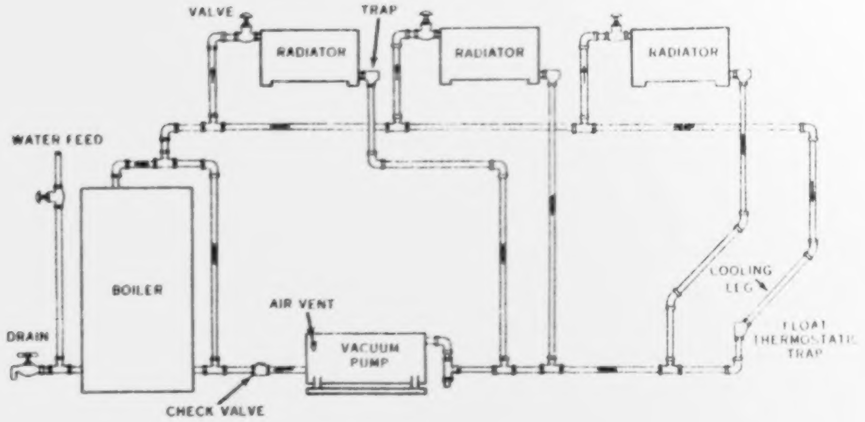

Figure 4-25. Two-Pipe Vacuum System

When fuel combustion stops, condensation of the steam which fills the unit can cause an induced vacuum which may prevent drainage of condensate from the heating units and cause a serious deficiency in boiler water supply. An equalizer line is usually installed between the supply main and the return piping to relieve this condition. The equalizer line shown in figure 4-25 includes a thermostatic trap which remains closed when steam is flowing, but when the steam flow stops, opens to equalize pressure in the supply and return mains. This permits the condensate to flow back to the pump receiver.

# INSULATION

Insulation is any type of material which has high resistance to heat flow. It is used to help prevent heat loss. Insulating brick is the form of insulation placed in the firebox of a furnace to minimize the escape of heat through firebox walls. Sheet insulation is used to cover the outsides of boilers, furnaces, and air ducts to reduce heat loss. Tube insulation is installed on distribution lines so that an excessive amount of heat is not lost from the heating media while going to the radiators. Insulation is also placed on return lines so that the condensate will not freeze before it returns to the boiler. Insulation should be fireproof, be verminproof, have lasting quality, be mechanically strong, be compact, and be light in weight.

The insulation used by the Air Force on heating units can be produced in a variety of forms, such as powered, sheet, block, blanket, tube, and roll. Powdered insulation is usually mixed with water and used to cover odd shapes, such as pipe tees, elbows, and valves. Sheet insulation is used to cover the warm-air and cold-air ducts, as well as the walls and ceilings of furnace rooms. Block and brick insulation materials are most often used to insulate the outside surfaces of boilers. Blanket insulation is used to cover the warm-air and cold-air ducts in a warm-air heating system. It is also used to cover the cold- and hot-water pipes in a steam or a hot-water heating system. Tube insulation (fabricated in tubular shapes) is used to insulate steam and hot-water pipes. Roll insulation, such as asbestos paper, is used to cover cold- and warm-air ducts for furnace casings in hot-air heating systems.

Magnesium asbestos insulation is the most common type used to cover heating equipment. Other insulating materials, such as rock wool, hair felt, glass wool, and fire felt are also used to limited degrees in Air Force installations.

## Types of Insulation

The various types of insulation in common use and their applications are explained in the following paragraphs of this section.

POWDERED INSULATION. Powdered insulation is procured in 25-, 50-, and 100-pound bags. It is mixed with water to prepare it for application. Usually four parts of insulation to one part of water, by volumn, will give a mixture of sticky consistency. The prepared insulation is applied to odd-shaped areas, such as elbows, tee's and valves, and compressed by hand until the excess moisture is removed from it. The insulation is then covered with cheesecloth or canvas to make it more durable. This covering should then be allowed to dry thoroughly before the area is heated.

SHEET INSULATION. Sheet insulation can be procured in various sizes and thicknesses. Sheet insulation is usually applied to flat areas, such as ducts, boiler room walls, and ceilings since it will not bend. Insulation of this type can be wired, screwed, nailed, or pasted in place.

BLOCK INSULATION. Block insulation held with plastic asbestos cement is normally used to cover the outside surfaces of boilers. When boilers are being insulated, the insulating value can be increased by first covering the boiler with ribbed metal. This procedure provides a dead-air space next to the boiler and gives higher insulating results that the use of the insulation alone. The application of ribbed metal to a boiler is illustrated in figure 4-16. After the boiler has been covered with ribbed metal, the block asbestos is applied.

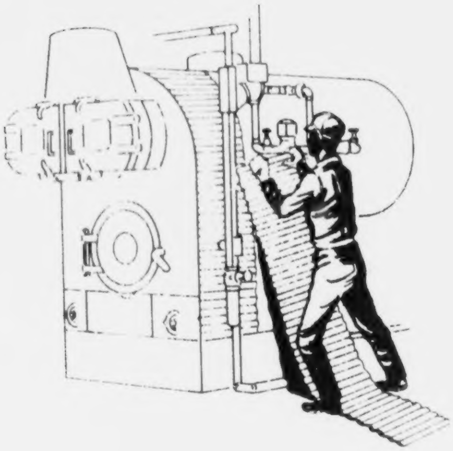

Figure 4-26. Applying Ribbed Metal to a Boiler

Several wires are passed loosely and vertically around the boiler shell (about 30 inches apart); when the insulating blocks are slipped under the wire and positioned with their edges closely butted together. Application of the blocks is started at the bottom and laid up on the sides. If the blocks do not come out evenly at the top, the spaces are filled in with small fitted pieces of block. After this the wires are drawn tight and other wires are then installed at about 6-inch intervals until the blocks are wired securely in place. Three or four more wires are passed horizontally around the bottom of the firebox so that they are below the rivet heads or other projections which will prevent them from slipping up. The wires are twisted into a cable and thus drawn tightly around the firebox. Several lacing wires can then be run over parts of the boiler shell above the firebox and wired to the cable around the firebox. Sufficient lacing wires should be added to insure that the blocks will be held firmly in place, crossing and tying the wires as necessary.

When the asbestos blocks are wired in place, the boiler is covered with 1 1/2-inch hexagonal galvanized wire netting (poultry netting). Openings are cut in the netting wherever necessary. When the openings in the wire netting tend to spread, wire is laced through the meshes of the netting around the opening to draw the meshes together. This makes the wire netting conform to the shape of the opening in the boiler.

The asbestos cement should be mixed in a tub or a large container, only enough water being used to make the cement workable. Best results can be obtained by thoroughly mixing the cement and applying it to the boiler when the boiler is hot.

The asbestos cement may be applied in one coat or two coats. If one coat is applied, the coating should be about 1 1/2-inch thick. If two coats are applied, each coat should be about 1/4-inch thick. Usually when the cement is applied in one thick coating, it has a tendency to fall off before it dries. Actually, for the inexperienced boiler operator, it is better to apply the cement in two coats. When applying two coats, take care to roughen the first coat with a trowel and allow it to dry thoroughly before the second coat is applied.

A canvas jacket is not always used to cover heating units. It will be found, however, that the protection afforded by it will prevent the insulation from crumbling. A heavy-weight canvas (preferably 8 ounce) is recommended for this purpose. Large pieces should be used to avoid making joints and laps. However, when joints are made the canvas should overlap about 2 inches.

The canvas should first be applied on the ends, turning the edges back over the sides. If it is installed in this manner, the canvas that is applied to the sides will lap over the first canvas applied forming a neat edge. The canvas is first dipped in cold water paste and wrung out by hand. Then it is spread neatly and smoothly over the surface of the insulated boiler. The canvas should not be applied closer to heated metal surfaces than 1/4 inch.

When canvas is to be fitted around openings, it should be cut after it has been dipped in the paste. Care is taken not to cut the openings too large. The edges can be trimmed neatly when the canvas is being pasted and smoothed into place. Short slits are cut in the edge of the canvas around the opeings to permit the canvas to lie smoothly when it is turned back on beveled edges. When the canvas is thoroughly dry, two coats of good oil paint or sealer should be applied if the covering needs water-proofing.

Insulation that is installed must be properly maintained to provide effectively its insulating qualities. Therefore, the next discussion is centered around maintaining insulation.

## Maintaining Insulation

It is necessary to repair all breaks and cracks in the insulation. Corners or exposed edges of insulation should be protected by installing iron guards. All insulation must be protected from moving parts which can mar, puncture, or damage it. Insulation must be protected from excessive pressures. Ladders, plants, piping, iron bars, etc., should never be allowed to rest on the insulation installed on a boiler or piping. One should never step or walk on insulation. The insulation around the pipes in dining halls can be protected with a sheet metal sleeve.

## SUMMARY

Steam heating systems are classified according to pipe arrangement, accessories used, method of returning the condensate to the boiler, method of expelling air from the system, or type of controls employed.

There are two types of mechanical return devices in common use: Mechanical return traps and condensate return pumps.

Steam can be obtained from several sources: Central Heating Plants, Pressure Reducing Stations, and Converters.

A steam heating system consists of the following elements: A steam source, supply piping, heating equipment, and return piping.

Steam systems may be classified by one or more of the following characteristics: Piping arrangement, pressure or vacuum conditions, and condensate return.

Insulation used by Air Force for heating application can be procured as powdered, sheet, block, blanket, tube, and roll.

## QUESTIONS

1. What are the two types of mechanical return devices used?

2. What are the sources of steam?

3. What are the two main types of exterior distribution systems?

4. What is the purpose of pressure regulators?

5. Explain the operation of a thermostatic trap.

REFERENCE

AFM 85-12, Vol 1, Operations and Maintenance of Central Heating Plants and Distribution Systems

AFM 85-12, Vol 2, Operation and Maintenance of Space Heating Equipment and Systems, and Process Heat Utilization

J3ABR54532 001-VII-1 thru VII-4

Technical Training

Heating Systems Specialist

# BOILER MAINTENANCE AND STEAM DISTRIBUTION SYSTEMS

April 1983

3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

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# EXTERNAL BOILER MAINTENANCE

## OBJECTIVE

Upon completion of this workbook you will be able to perform external boiler maintenance with instructor assistance.

## PROCEDURE

This workbook is divided into six exercises:

Exercise 1 - Replace and Test Safety Valve

Exercise 2 - Replace Gauges

Exercise 3 - Cleaning Water Column and Gage Glass

Exercise 4 - Inspect and Replace Soft Plug

Exercise 5 - Checking and Cleaning Fireside

Exercise 6 - Replace or Repair Refractory Material

## EXERCISE 1

### Replace and Test Safety Valve

## PROCEDURES

Replace safety valve.

CAUTION: Remove all jewelry.

1. Obtain tools from instructor.
2. Disassemble safety valve exhaust piping.

NOTE: Six foot step ladder may be needed; make sure ladder is held steady.

3. Remove safety valve.
4. Replace safety valve.
5. Reassemble safety valve exhaust piping.

NOTE: Exhaust piping will be placed in position by last student performing criterion.

Test safety valve.

CAUTION: Discharge opening must be pointed away from personnel.

1. Hook up safety valve and pressure gauge to air line.
2. Open globe valve to at least 80% of safety valve set pressure.
3. Lift lever for at least 10 seconds.

4. Close valve by suddenly releasing lifting lever.

5. Open globe valve until air pressure lifts safety valve.

6. Check pressure gauge to see what pressure safety valve lifted.

   NOTE: Inform instructor of gauge pressure.

7. Close globe valve on air line.

8. Remove safety valve and pressure gauge from air line.

9. Secure equipment.

## EXERCISE 2

## Replace Gauges

PROCEDURES

CAUTION: Remove all jewelry.

1. Obtain tools from instructor.
2. Position stepladder.

   NOTE: Make sure ladder is held steady.
3. Close gauge cock valve.
4. Remove gauge.
5. Obtain new gauge from instructor.
6. Replace gauge.
7. Open gauge cock valve.
8. Return tool to instructor.

## EXERCISE 3

## Clean Water Column and Gage Glass

PROCEDURES

Clean Water Column

CAUTION: Remove all jewelry.

1. Drain boiler down below waterside connection of water column.

2. Obtain tools from instructor.

3. Unhook electrical connections if necessary.

   NOTE: Make sure electrical power is off.

4. Remove bolts from water column assembly.

5. Carefully remove float assembly.

6. Remove gasket from flange surface (putty knife).

7. Open water column drain valve.

8. Check float chamber for scale, dirt, mud, etc. (Use flashlight)

9. Wash out float chamber with water hose.

10. Check float chamber for cleanliness.

11. Check float assembly for the following items:

    a. Bent rod

    b. Scale on float

    c. Hole in float

    d. Collapsed float

    e. Waterlogged float

12. Report any discrepancies to instructor.

13. Using new gasket reassemble water column.

    NOTE: Make sure bolts are tight.

14. Reconnect electrical connections if unhooked.

Clean Gage Glass

PROCEDURES

1. Obtain tools and equipment from instructor.

2. Unscrew top packing nut.

3. Unscrew bottom packing nut.

4. Remove top and bottom packing washer.

5. Remove gage glass from gage glass valves (do not drop glass).

6. Clean gage glass using water (use caution when cleaning).

7. Clean gage glass valves.

8. Repack gage glass valves (if necessary).

9. Inspect gage glass washers (replace if necessary).

10. Reinstall gage glass.

11. Tighten top and bottom packing nuts.

    NOTE: Last student to perform criterion will fill boiler to normal operating level and check for leaks.

12. Secure equipment.

## EXERCISE 4

### Inspection and Replacement of Soft Plug

PROCEDURE

NOTE: Complete the following statements using the study guide as a reference.

1. What is the purpose of fusible plugs? ______________________

2. What is the melting point of most fusible plugs? ______________________

3. How often should fusible plugs be replaced? ______________________

4. Does the boiler have to be taken out of service to replace fusible plug? ______________________

5. When do you inspect the fusible plug? ______________________

6. Should old fusible plug be refilled with a tin alloy for re-use? ______________________

7. What do you do if the metal in the fusible plug does not appear sound? ______________________

8. What action would a technician take if a fusible plug was found discharging steam? ______________________

## EXERCISE 5

## Cleaning and Checking Fireside

PROCEDURES

Clean Fireside

CAUTION: Remove all jewelry. Use goggles and gloves for protection from wire brushes getting dirt in the eyes and injury to hands.

1. Obtain equipment and tools from instructor.
2. Remove back from boiler.

   NOTE: Use caution when removing, back pieces are heavy. May require two men to handle back pieces. Do not lose nuts.
3. Clean tubes with tube brush.

   NOTE: Push brush all the way through the tubes. Do not stop midway in tube and pull back out.
4. Clean flat surfaces with wire brushes.
5. Clean smoke box or stack area with wire brush.
6. Remove loose soot from boiler (use vacuum cleaner if possible).

Check Fireside

1. Obtain equipment from instructor.
2. Check fireside for cleanliness.
3. Check tube ends for leaks.
4. Check smokebox or stack area for corrosion.
5. Replace back on boiler.

   NOTE: Make sure gasket is on straight. DO NOT strip bolts. Make sure all bolts are tight.

804

## EXERCISE 6

### Repair and Replace Refractory

PROCEDURES

NOTE: Complete the following statements using the study guide as a reference.

1. List two methods of cleaning a steaming boiler.

   a. ______________________________

   b. ______________________________

2. What temperature should the boiler water be before it is permissible to allow a man to enter the boiler? ______________________

3. 1/16" of soot = approximately ____________ heat loss.

4. List six statements that give the purpose of boiler refractory.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

   f. ______________________________

5. List three factors that influence the life of the furnace refractory.

   a. ______________________________

   b. ______________________________

   c. ______________________________

6. What is spalling?

7. What is boiler panting?

8. What is slagging?

9. Name the three layers of refractory material in the combustion chamber.

   a. ______________________________

   b. ______________________________

   c. ______________________________

10. What is used for securing standard firebrick?

11. What is added to the combustion chamber to allow for expansion?

12. What is usually used for patching brick work?

13. Why must you punch holes thru plastic fire brick?

14. What is used to protect studded water wall tubes, some headers and some drums?

15. What type refractory material needs a form?

16. What size joint is between each firebrick?

17. What type of maintenance is refractory work classified as?

18. Repair and replace refractory material

    a. using firebox boiler trainer, remove insulating block, insulating brick, and standard firebrick.

    b. clean firebox.

    c. replace insulating block, insulating brick and standard firebrick.

# INTERNAL BOILER MAINTENANCE

## OBJECTIVE

Upon completion of this workbook, you will be able to perform internal boiler maintenance with instructor assistance.

## PROCEDURE

This workbook is divided into six exercises:

Exercises 1 and 2 - Maintain Boiler Waterside Components

Exercise 3 - Internal Corrosion

Exercises 4 and 5 - Hydrostatic Test

Exercises 6 - Tube Repair

## EXERCISE 1

### Maintain Boiler Waterside Components

## PROCEDURE

NOTE: Complete the following statements using the study guide as a reference.

1. Why should a man be stationed outside the boiler before anyone enters?

2. All electrical equipment should be properly ______________________.

3. List two methods for cleaning the waterside of boilers.
   a. ______________________
   b. ______________________

4. What is used to loosen scale in fire-tube boilers? ______________________

5. What is used to loosen scale in bent-tube water tube boiler? ______________________

6. What is used to remove loose scale from boilers? ______________________

7. List the two combinations of chemicals which can be used for boiling out a boiler.
   a. ______________________
   b. ______________________

8. How often is the boiler blown down in the boiling out process?

9. What is the purpose of hand holes and manholes?

10. What temperature can the boiler be safely drained and entered into?

# EXERCISE 2

## Maintain Boiler Waterside Components

### PROCEDURES

**CAUTION**: Remove all jewelry.

1. Obtain tools from instructor.
2. Drain boiler using bottom blowdown valves.

   NOTE: Use proper procedures for blowing down boiler and make sure water temperature in boiler is below 200°F. Open air vent. Exercise 3, page 2-4 will be accomplished during this exercise.

3. Open waterside by removing hand holes.
4. Using water hose, flush out boiler.
5. Using water hose, wash down all interior areas of boiler.

   NOTE: Boiler is clean when water coming out bottom of boiler is clear. Have instructor check work at this time.

6. Using flashlight inspect boiler for scale and oxygen pitting.

   NOTE: If boiler has large amounts of scale, notify instructor, boiling out procedures may have to be instituted. If large amounts of oxygen pitting are found, notify instructor.

7. Clean hand hole plug gasket area.

   NOTE: After plug is clean, have instructor check work.

8. Inspect interior of hand hole area for cleanliness.
9. Obtain new hand hole gasket and replace hand hole.
10. Close blowdown valves.

    NOTE: Use proper procedures for closing valves.

11. Fill boiler to approximately middle of gauge glass.

    NOTE: Make sure air vent is open. Water hose may be used or by pass on feed water system. Feed water pumps will be used only if necessary.

12. Inspect hand holes for leaks.

    NOTE: Tighten if necessary, do not over tighten.

13. Close air vent.
14. Clean area around high pressure boiler.
15. Return tools to instructor.

## EXERCISE 3

## Inspect for Corrosion

PROCEDURE

CAUTION: Remove all jewelry.

NOTE: This exercise will be done while boiler is open for completion of exercise 2.

1. Obtain tools from instructor.

2. Using flashlight inspect all interior parts of waterside for oxygen corrosion.

3. Notify instructor if large amounts of oxygen corrosion are found.

## EXERCISE 4

## Hydrostatic Test

PROCEDURES

NOTE: Complete the following statements using the study guide as a reference.

1. What must be done before boilers can be inspected?

   a. ______________________________________________

   b. ______________________________________________

   c. ______________________________________________

2. What equipment will be inspected?

   a. ______________________________________________

   b. ______________________________________________

3. All steam boilers get inspected when?

4. How many types of inspections are there?

5. Identify each type of inspection.

   a. ______________________________________________

   b. ______________________________________________

   c. ______________________________________________

   d. ______________________________________________

   e. ______________________________________________

6. What type of inspection is performed on the expansion tank of a HTW system?

7. Define hydrostatic test.

8. At what pressure is a hydrostatic test done? ______________________

9. What temperature is the water that is used in a hydrostatic test? __________

10. What must be done to the safety valve during a hydrostatic test?

11. If the pressure controls cannot withstand the hydrostatic pressure applied, what must be done to them?

12. With what type of inspection is hydrostatic test included?

## EXERCISE 5

## Hydrostatic Test

PROCEDURES

CAUTION: Remove all jewelry.

NOTE: High pressure boiler that was previously worked on will be used for this exercise.

1. Obtain tools from instructor.

2. Using step ladder, gag or remove safety valve.

   NOTE: Make sure ladder is kept steady. Safety valve gags may not be available, safety valve must be removed.

3. Remove pressure controls (if necessary).

   NOTE: Check with instructor to see if pressure controls must be removed.

4. If safety valve was removed, plug or cap opening on boiler.

5. If pressure controls were removed, plug or cap openings on boiler.

6. Open feedwater system.

7. Turn on electrical system for pumps.

8. Turn on master switch on control panel.

9. Fill boiler completely and apply hydrostatic pressure.

   NOTE: The pump will be operated by manual mode. Remember hydrostatic pressure is 1 1/2 times safety valve set pressure.

10. Turn off pump when hydrostatic pressure is reached.

11. Check for stress areas.

12. Check for leaks at hand holes.

    NOTE: Notify instructor if leak is found; after instructor has looked at leak you will be instructed on what to do.

13. After test is complete, return boiler water level to proper place.

14. Replace pressure controls (if removed).

15. Replace safety valve.

16. Return tools to instructor.

17. Clean up area around high pressure boiler.

18. Secure equipment.

## EXERCISE 6

## Minor Tube Repair

CAUTION: Remove all jewelry, use safety precautions when working with boiler tube repair trainer.

NOTE: Use test procedure 1 or 2 as directed by instructor.

### TEST 1. Plugging Boiler Tubes

1. Proceed to boiler area with instructor.

2. Draw hand tools for plugging boiler tubes.

3. Instructor will assign you a boiler tube and plug.

4. Clean interior of tube and exterior of plug of all scale, oil, burns and foreign matter.

5. Insert small end of plug into tube end and tap snugly into place; insure plug is tapped evenly and not too tightly.

6. Remove each plug from the tube end and clean plugs and all tools. Return plugs, tools and materials to the proper place.

7. Clean area before returning to classrooms.

### TEST 2. Rerolling Boiler Tubes

1. Proceed to boiler area with instructor.

2. Draw hand tools for rerolling tubes.

3. Instructor will assign you a boiler tube and tube expander.

## BOILER LAY UP

### OBJECTIVE

Upon completion of this workbook, you will be able to answer questions about boiler lay up using the wet and dry methods.

### PROCEDURE

### EXERCISE 1

NOTE: Complete the following statements using the study guide as a reference.

1. What is the purpose of boiler lay up?

2. When is the dry method or boiler lay up used?

3. What can be used to absorb moisture in the dry method?

   a. ____________________

   b. ____________________

4. For what length of time is the wet method used? ____________________

5. What chemicals are used in the wet method?

   a. ____________________

   b. ____________________

6. What concentration level of caustic soda is maintained?

7. What is the concentration level of sodium sulfite in the wet method?

8. What pressure is maintained in the boiler?

9. How can you tell if chemical concentrations used in the wet method are at proper levels?

10. Why must you clean the external surfaces of the boiler when using the dry method?

# STEAM DISTRIBUTION SYSTEMS

## OBJECTIVE

Upon completion of this workbook you will be able to operate steam distribution system with instructor assistance.

## PROCEDURE

This workbook is divided into eight exercises:

Exercise 1 - Maintain Steam Distribution

Exercise 2 - Maintenance of Pressure Reducing Station

Exercise 3 - Expansion Joints

Exercise 4 - Distribution System Conduits

Exercise 5 - Installation and Maintenance of Converters

Exercise 6 - Maintenance On Steam Distribution System

Exercise 7 - Steam Trap Maintenance

Exercise 8 - Apply Insulation

## EXERCISE 1

### Maintain Steam Distribution

## PROCEDURE

NOTE: Complete the following statements using the study guide as a reference.

1. List the pressure ranges and their different uses.

2. What major types of distribution systems are there?

3. What are the two types of underground systems?

   a. ____________________

   b. ____________________

4. What are the two types of aboveground systems?

   a. ____________________

   b. ____________________

5. What two types of expansion joints are there?

a. ______________________________

b. ______________________________

6. How much will a wrought-iron pipe 800 feet long expand? (This pipe is carrying steam at 25 psig.)

7. What are the three types of pressure reducing valves?

a. ______________________________

b. ______________________________

c. ______________________________

8. How is the spring-loaded pressure reducing valve adjusted?

9. How is the temperature changed on the temperature regulating valve?

10. Why is an expansion loop better than an expansion joint?

## EXERCISE 2

## Maintenance of Pressure Reducing Station

CAUTION: Remove all jewelry.

1. Fire up boiler.

2. Cut in distribution system when boiler reaches 30 psig.

   NOTE: Make sure all drains are open; close when steam appears.

3. Place into operation the two pressure reducing valves (PRV).

   a. Trace steam line from boiler to station making sure all the valves are open.

   b. Slowly open gate valves on either side of spring-operated PRV.

   c. Slowly open globe valve on external pilot line.

   d. Slowly open gate valve to trap.

   e. Slowly open gate valve to condensate line.

   f. Slowly open globe valve on external pilot line.

   NOTE: If the PRVs are leaking, bypass the PRVs and repair them as required.

4. In order to bypass automatic PRV, proceed as follows:

   a. Secure the gate valves on either side of the PRV that is leaking.

   b. Slowly open globe valve on bypass.

   CAUTION: Watch gauge as you are opening valve so that the pressure does not exceed the amount used on the equipment.

5. To come off bypass after repairs have been made, proceed as follows:

   a. Secure globe valve.

   b. Slowly open gate valves on either side of PRV.

   c. Slowly open globe valves on external pilot lines.

   NOTE: Do not allow the steam pressure going to the equipment to exceed 25 psi. If the pressure on the low side of the spring-operated valve exceeds the desired amount, adjust the adjustment nuts. Position weights to get the pressure desired when using the weight and level PRV.

6. Have the instructor check your work and supply the steam to the station.

## EXERCISE 3

### Expansion Joints

NOTE: The type of maintenance depends upon the type of expansion joint. Determine the type of expansion joint and complete the maintenance.

1. Slip Type --
   a. Check for proper alignment.
   b. Check for proper packing.
   c. Thoroughly clean and lubricate.
   d. Adjust or replace packing as required.
   e. Check the flange-to-flange distance.
   f. Inspect the signs of erosion, corrosion, wear, deposits and binding.
   g. Repair or replace defective parts as required.

2. Bellows Type --
   a. Check bellows joint for misalignment, corrosion and erosion.
   b. Check the amount of travel between cold and hot conditions.
   c. If joint fails, replace the bellows section.

3. Expansion loops --

   Inspect the proper alignment.

4. Have the instructor check your work.

## EXERCISE 4

## Distribution System Conduits

PROCEDURE

NOTE: Complete the following questions. Use study guide as a reference.

1. What types of materials are used for conduit systems?

2. What are the two types of conduit systems?

   a. ______________________________

   b. ______________________________

3. What is the purpose of manholes?

4. What do you check manholes for?

5. What is the main problem area for conduit systems?

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# EXERCISE 5

## Installation and Maintenance of Converters

PROCEDURE

NOTE: Complete the following questions. Use study guide as a reference.

1. What is a converter?

2. What can be used as the heating medium?

   a. ______________________________

   b. ______________________________

3. What are the tubes or coils used for in a converter?

4. In a steam converter where does the water flow?

5. In a HTW converter where does the HTW flow?

6. What must be installed after a steam converter?

7. What pressure of steam can be obtained using a converter?

8. What device will protect the converter?

## EXERCISE 6

## Maintenance on Steam Distribution System

PROCEDURE

NOTE: Complete the following statements. Use study guide as a reference.

1. What are steam traps?

2. How are steam traps classified?

3. Where are steam traps located?

4. What trap is activated by temperature changes?

5. What trap must be primed?

6. Which trap operates by the bending of a bimetallic unit?

7. What is the purpose of the strainer?

8. What is done to a steam trap annually?

9. What two types of condensate return systems are there?

10. In the gravity return system, what is the Hartford loop used for?

11. What are the two types of mechanically returned condensate?

## EXERCISE 7

### Steam Trap Maintenance

CAUTION: Insure steam has been secured.

NOTE: The instructor will assign you a trap.

1. Isolate the trap by securing the proper inlet and outlet valves.
2. Remove trap, carry to workbench and remove piping.
3. Disassemble trap by removing trap cover.

   CAUTION: DO NOT use improper tools. If the system has had pressure on it, be careful that the water or pressure in the trap does not burn you. Be sure that the valves are not leaking at the seat.

4. Remove internal parts of the trap.
5. Inspect internal parts for corrosion, wear, defective bellows, buckets or floats.
6. Replace or repair parts as required.

   NOTE: Use only matched sets of replacement valves and seats. DO NOT change the weight of floats or buckets, operation may be affected.

7. Clean outlet valve part.
8. Clean up trap casing and covers for excess gasket material. Remove all frozen material from trap casing.

   NOTE: Have the instructor check your work, then proceed as follows.

9. Install internal parts.
10. Replace gasket using a non-hardening sealing compound, such as grease or graphite if sealing compound is used.
11. Install trap cover, tightening bolts evenly.

    NOTES: Tighten bolts in a star sequence.

    Use nipples and union taken out of step 2. Replace fittings if necessary.

12. Open proper valves to place trap into operation.
13. Check for leaks.

    NOTE: Have instructor check your work.

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## Cleaning Strainers

1. Isolate the strainer by securing proper valves.
2. Remove basket.
3. Clean basket compartment.
4. Replace gasket as required.
5. Install basket.
6. Open proper valves and check for leaks.

## EXERCISE 8

## Applying Insulation

1. Tube Insulation --

   a. Select proper size.

   b. Place on pipe.

   c. Cement or paste loose flap, if provided. If not, wrap tube insulation with cheesecloth and smooth it over with wheat paste to hold cheesecloth tight until wheat paste dries; use metal strips.

2. Powder Insulation --

   a. Mix insulation with water to a very stiff consistency.

   b. Apply to odd shapes such as elbows, valves or around tanks, stacks, etc.

   c. Wrap with cheesecloth and apply wheat paste.

3. Duct Insulation --

   a. What is used to hold insulation on ducts?

   ______________________________

   b. What is a common type of duct insulation?

   ______________________________

   c. Why is insulation used on warm air ducts?

   ______________________________

   ______________________________

## EXERCISE 8

## APPLYING INSULATION

MATERIAL NEEDED:

-tools
-cheesecloth
-tube insulation
-wheat paste
-powdered insulation
-pails

PROCEDURES:

(1) Tube Insulation--

a. Select proper size insulation.

b. Cut to size with keyhole saw.

c. Place only over pipes.

d. Secure with insulation tape.

(2) Powdered Insulation--

a. Mix insulation in a pail to a very stiff consistency.

b. Apply to odd shapes only (ex. valves, elbows, reducers).

c. Shape and smooth surfaces.

d. Insure powdered insulation is even with tube insulation and the ends are squared off.

(3) Wheat Paste--

a. Mix wheat paste as directed.

b. Cut and separate cheesecloth.

c. Dip into paste then wrap around powdered insulation.

d. Smooth surfaces.

(( HAVE INSTRUCTOR INSPECT WORK ))

(4) Clean tools and pails with water.

Clean work area.

(5) Duct Insulation--

a. What is used to hold insulation on ducts?

________________________________________

b. What is a common type of duct insulation?

________________________________________

c. Why is insulation used on warm air ducts?

________________________________________

________________________________________

## Cleaning Strainers

1. Isolate the strainer by securing proper valves.

2. Remove basket.

3. Clean basket compartment.

4. Replace gasket as required.

5. Install basket.

6. Open proper valves and check for leaks.

STUDY GUIDES
J3ABR54532 001-VIII-1 Thru VIII-5

Technical Training

Heating System Specialist

# BOILER WATER TREATMENT AND CORROSION CONTROL

May 1983

3700 TECHNICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

RGL: 9.5

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Supersedes SGS J3ABR54730 001-V-1 thru V-5, March 1981. (Copies of the superseded publication may be used until supply is exhausted.)

## EXPLANATION OF TERMS

ACCUMULATIONS--Collections.

ADHERING--Sticking.

ADJUST-- Regulate.

ADJUSTMENT--To regulate.

ALIGNMENT--Putting into precise position.

ALKALINE--Having the properties of salt.

ALLOY--Mixture of base metals.

ANNUALLY--Once a year.

ANODE--Positive terminal of cell.

ARRANGEMENT--Having been put in order.

ASBESTOS--A fire resistant material.

ASSEMBLED--Collected, put together.

ATMOSPHERE--Air.

AUTOMATIC--Self acting.

AUXILIARY EQUIPMENT--Extra equipment necessary.

AVAILABILITY--To have close to use.

BAFFLES--Used to direct flow of gases, steam or water.

BELLOWS--Expandable device used in traps, valves and controls.

BIMETALLIC--Composed of two different metals.

BLOWDOWN--Discharge, drain partially.

BOILER--Enclosed vessel used to generate steam.

BOUNDARY--A bounding or separating line.

BREECHING--Bottom of a pulley block.

BRICKWORK--Work of or with brick.

BURNER--Part of boiler which produces flame.

BYPASS--To go around.

CALIBRATE/CALIBRATION--Find, change or mark of graduation.

CAM-ACTUATED--Operated or controlled by a cam.

CAPACITY--Measure of content, maximum output.

CAPILLARY--Small bore tube used to transmit pressure.

CASING--Body.

CASTABLE--Able to be molded.

CATHODE--Negative terminal of cell.

CAULKED--Stopped up, sealed against leakage.

CAUSTIC--Capable of destroying or eating away by chemical action.

CENTRIFUGAL--Going or acting in a direction away from a center or axis.

CERTIFIED--Authorized by a certificate.

CHAMBER--Cavity or compartment.

CHARACTERISTICS--Traits, qualities or properties.

CIRCULATE--To move.

CIRCULATION--The movement of.

CLASSIFIED--Divided into classes.

CLINKERS--Stony matter fused together.

COMBINATION--Two or more.

COMPENSATE--Make up for.

COMPONENTS--Parts of.

COMPRESSION--Squeezing or compacting with power.

CONDENSATE/CONDENSE--Steam turned back into water.

CONDITIONS--Provisions or working status.

CONDUCTIVITY--Degree of ability to transmit electricity.

CONNECTED/CONNECTION--Attach to.

CONSISTENCY--Thickness.

CONSTANT--Always or lasting.

CONSTRUCTION--Made or made of.

CONTACTS--Electrical touching points.

CONTINUOUS--Always or lasting.

CONTRACTION--Shrinkage.

CONTROL--Having power over.

CONVERTERS--Device used to change heating mediums (i.e., steam to water).

CORROSION--Act of eating away by degrees.

CRYSTAL--A body formed by solidification of a chemical element or compound.

CYCLE--A sequence of a recurring succession of events.

DAMAGE--Destroy or destruction.

DAMPERS--A plate used for regulating the flow of air or gases.

DEAERATE/DEAERATING/DEAERATION--Removal of air from water.

DEFECTIVE--Not as it should be.

DEMAND--Requirement.

DEPOSITS--Collections of.

DIAGRAMS--Simplified drawings.

DIAPHRAGM--Thin membrane divider or partition.

DIFFERENCE--Sum of subtraction.

DILUTION--Act of reducing strength.

DIMENSIONS--Measurements of an object's shape.

DISCHARGE/DISCHARGED--Remove, throw out.

DISMANTLE--Take apart.

DISSOLVE--To cause to disperse or pass into solution.

DISTRIBUTED/DISTRIBUTION--Convey, give out or supply portions of.

DOWNWARD--From a higher place to a lower.

ECONOMIZER--Closed feedwater heater using hot stack gases as a heating medium.

EFFICIENCY/EFFICIENT--Measurement of operation or ability.

ELECTRICAL--Pertaining to electricity.

ELECTROLYTE--Nonmetallic conductor of current.

ELECTRONIC--Pertaining to electronics.

ELEMENT--A part or piece of.

EMERGENCY--Pressing need calling for immediate action.

EQUALIZE--To make equal.

EQUILIBRIUM--Balance.

EQUIPMENT--Implements used in an operation or activity.

EVALUATE--To examine and judge.

EXCESSIVE--Going beyond a limit.

EXHAUST--Already used once.

EXPAND/EXPANDED/EXPANSION--Increase in size or volume.

EXPLOSIONS--Violent outbursts.

EXPOSED--Uncovered or unprotected.

EXTERNAL--Outside.

EXTREME--Maximum.

FACILITIES--Something built, installed or established to serve a purpose.

FAILURE--Falling short.

FEATURE--A special attraction.

FEEDWATER--All water put or to be put into a boiler.

FIREBOX--Chamber that contains a fire.

FIREBRICK--Used to build furnace refractories.

FITTINGS--Various controlling devices installed on a boiler.

FLASHING--Rapid conversion of hot water to steam due to a pressure drop.

FLEXIBLE--Bendable or pliable.

FLUCTUATION--Changing from a norm.

FORCED--Done or produced with effort.

FROST LINE--Depth to which the ground freezes.

FUNCTION/FUNCTIONING--Work, perform.

FURNACE--Where initial combustion and burning of fuel takes place.

FUSIBLE PLUG--Brass plug with tin core, used as a low water alarm.

GASKET--A ring of material fitted tightly around a joint to keep it from leaking.

GENERATE/GENERATED--To make or produce.

GRADUATED--Marked with degrees of measurement.

GRAVITY--Force that draws objects toward the center of the earth.

HAND-HOLE--Hand sized orifice in a boiler to facilitate maintenance.

HARMFUL--Damaging, injurious.

HEADER--Pipe or tube shared by two or more boilers, objects or devices.

HEATING--The act of increasing the temperature.

HORIZONTAL--Parallel to the horizon.

HYDRAULIC--Operated, moved or effected by a liquid; i.e., water or oil.

HYDROSTATIC TEST--Filling boiler with water to a pressure one and one-half times the safety valve setting.

IGNITION--Act of setting on fire.

IMPINGEMENT--Encroachment or infringement.

INCORPORATE--Unite.

INCREASE--Add to.

INDEFINITELY--Unknown amount of time.

INDEPENDENT--Not depending on.

INDICATE/INDICATING--Point, direct or show.

INDUCED--Sucked up, brought on.

INJECTOR--A unit to force water into a boiler.

INLET--Entry.

INSPECT/INSPECTION--To check or look carefully.

INSTALL/INSTALLED--To set up for use.

INSTALLATION--Air Force bases or properties which contain heating equipment.

INSTRUCTIONS--Procedures.

INSULATE/INSULATION--Protect or cover.

INTEGRATE/INTEGRATED--Mix together.

INTERFERE--To hinder.

INTERMITTENT--Coming and going at intervals.

INTERNAL--Inside.

INVERTED--Upside down.

ISOLATING VALVE--Valve used to separate a device from the main flow.

JURISDICTION--Control or authority over.

LAMINATIONS--Layers of bonded materials.

LATTER--Relating to the last or more recent.

LETHAL--Deadly.

LIMITATIONS--Limits.

LINKAGE--System of bars, rods or links.

LOCATED/LOCATION--Indicates place or site.

LONGITUDINAL--Placed or running lengthwise.

LUBRICATE/LUBRICATED/LUBRICATION--To make slippery, usually with grease or oil.

MAGNESIUM--A form or type of insulation.

MAINTAIN--To keep in existing state.

MAINTENANCE--To service or repair a piece of equipment.

MALFUNCTION--Failure to operate normally.

MANUAL/MANUALLY--Worked by hand.

MANUFACTURE/MANUFACTURER--Make, maker.

MASONRY--To do with stone.

MAXIMUM--Most or highest limit.

MECHANICAL--Operated by a machine.

MECHANISM--Mechanical operation or action.

METER--Indicating type measuring device.

METHOD--Way of doing.

MINIMUM--Least or lowest limit.

MISALIGNMENT--Not aligned.

MOISTURE--Wetness.

MORTAR--Mixture of cement of lime with sand and water to hold bricks together.

MOVEMENT--Change of place, position or posture.

NIPPLE--Short piece of pipe.

NONCONDENSABLE--Unable to be condensed.

NON-RETURN VALVE--Valve permitting flow only in one direction.

NORMAL--Average.

OBSERVATION-Watching.

OBTAINED--Got or received.

OPERATE/OPERATING/OPERATION/OPERATIONAL--Relating to work.

OPERATOR--One who operates.

OPTIMUM--Best.

ORIFICE--Hole or opening.

OUTLET--Exit.

OXYGEN--A gas without color, taste or odor, and is a chemical element ($O_2$).

PACKAGE--Moderate sized unit with all essentials.

PASSAGE--Channel, course, tunnel or corridor.

PENETRATE--Pass into or through.

PERCENT--Reckoned on the basis of a whole divided equally into one hundred parts.

PERFORATIONS--Holes.

PERIODICALLY--Fixed intervals between set times.

PERMANENT--Fixed or lasting.

PERMISSIBLE--Allowed.

PERSONNEL--People of a unit or group.

PISTON--A sliding piece moved by or moving against a liquid or gas.

PLASTIC FIREBRICK--Unburned brick that can be shaped to form refractory linings.

PNEUMATIC--Operated by air.

POSITION--Place or posture.

PRECAUTION--To be on one's guard.

PRECIPITATES--To separate from solution or suspension.

PREFABRICATED--Already made.

PREHEATERS--Equipment used to heat something before it is used.

PRELIMINARY--Something that precedes.

PREOPERATION/PREOPERATIONAL--Before operating.

PRESSURE--Force exerted.

PREVENT/PREVENTING--To stop from happening.

PRIMING--Filling with water.

PRINCIPAL--Most important.

PROCEDURE--Steps followed in a definite order.

PROJECTING--Going beyond.

PROLONGED--To lengthen the time of.

QUALIFIED--Complied with the specific requirements.

QUALITIES--Peculiar and essential characteristics.

QUARTERLY--Four times a year, three months or 90 days.

QUESTIONABLE--Doubtful.

RECOMMEND--To attract favor to.

RECTIFICATION/RECTIFYING--To make unidirectional.

REDUCE/REDUCING/REDUCTION--Decrease or make smaller.

REFRACTORY--Heat resisting nonmetallic ceramic material.

REGENERATIVE--Ability to form or create again.

REGULATE/REGULATING/REGULATOR--To control the flow of.

RELAY--Electrical device used to delay the flow of current.

REMOVED--Taken away from.

REPLACE/REPLACEMENT--Substitute.

REQUIRE/REQUIRED/REQUIREMENTS--Needed or essential.

RESIDUE--Remains of.

RESISTANCE--Opposition against.

RESPIRATORY--Breathing.

REVOLVING--Turning around on an axis.

RIVETED--Fastened or united with rivets.

ROTATION--The turning of a body on an axis.

SAFETY--Condition of being safe from or causing hurt, injury or loss.

SCANNER--Control component used to sense flame.

SEDIMENT--Settlings of impurities.

SEQUENCE--The order of progression.

SETTING(S)--Material that covers an inside surface of a boiler furnace.

SHALLOW--Opposite of deep.

SHRINKAGE--Amount of decrease in size.

SIMULTANEOUSLY--At the same time.

SOLUTION--Liquid containing a dissolved substance.

SPALLED/SPALLING--The flaking and chipping of brick surfaces.

SPECIFICATIONS/SPECIFIED--Detailed precise presentation of something.

STANDARD--Something established as a rule for measuring quantity, weight, extent, value or quality.

STATIONARY--Fixed, immobile.

SUFFICIENT/SUFFICIENTLY--Enough.

SUPERHEATER--Tubes in steam boilers that add extra heat to the steam before exiting the boiler.

SUSPENDED--To maintain from falling or sinking.

SYSTEM(S)--Regularly interacting or interdependent group forming a unified whole.

TAPERED--Becoming gradually smaller toward one end.

TEMPERATURE--A measurement of heat in degrees Fahrenheit or Celsius.

THERMODYNAMIC--A steam trap operated by the dynamics of heat.

THERMOHYDRAULIC--A feedwater regulator operated by expansion and contraction of water.

THERMOSTATIC--A feedwater regulator operated by the expansion and contraction.

THICKNESS--Measurement from one side through to the other.

THROTTLING--To prevent or check activity of.

TURBINE--Rotary engine actuated by the reaction or impulse of a current of fluid or gas.

TYPICAL--Common.

UNCONDENSED--Not condensed.

UPWARD--From lower to higher.

VACUUM--Devoid of matter.

VALVE--Mechanical device used to stop or permit the flow of fluids or gases.

VENTILATE/VENTILATION--To air out.

VERIFICATION--Act or process of confirming.

VERTICAL--In an upright or up-and-down motion or position.

VIBRATION--Periodic motion in alternately opposite directions.

VOLTAGE--Unit of electrical potential or potential difference.

WATER--Contains two parts hydrogen and one part oxygen expressed as $H_2O$.

WATER COLUMN--A steam boiler external fitting used to prevent fluctuations of water in the gauge glass.

WITHDRAWING--Taking out or away.

YEARLY--Once a year.

ZEOLITE--Any of various natural or synthesized silicates or similar structure used in water softening.

3770 Technical Training Group
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Sheppard Air Force Base, Texas

# SOURCES OF WATER

## OBJECTIVE

Given information, explain basic facts about sources of water and their characteristics with 80% accuracy.

## INTRODUCTION

Have you ever wondered how water is affected by its surroundings? Water, in nature, is never really pure. When water falls from the clouds in its purest natural state, the water collects some dust, gases and other foreign matter. After water has run over the surface of the ground or percolated through rock layers, water impurities have greatly increased due to the fact that water is practically a universal solvent and dissolves a little of everything it touches. Therefore, water requires treatment or conditioning before it is fit for use by military, industry and the home. Water impurities may mean either wealth or worry to the Air Force in successful operation. Impurities are classed as dissolved gases, dissolved solids, suspended solids and bacteria. Information on the sources and characteristics of water which will benefit you is contained under the following main topics of this study guide.

--- Sources of Water

--- Characteristics of Water

--- Potential Hydrogen Scale

--- Major Contributors to Corrosion

In the last block you discussed boiler design and construction features. Now that you know how boilers are built, how to operate them, and how they are useful in today's society, it will be of your concern as to how they should be cared for. You will also want to know what impurities in water could cause hazards in boiler operations and which impurities in water could cause inefficient operation, but first you must know the sources of water and its contents. This will be discussed in our opening paragraphs.

## INFORMATION

## SOURCES OF WATER

There are four sources of water: surface, ground, sea and collected. Surface and ground are the most common sources of water used by the Air Force. Seawater is not normally used because it is expensive to separate the sale from the water. Collected water will only be used when location requires it.

### Surface Water

STREAMS. Streams are the most common sources of surface water supply. Turbidity and mineral content vary with the flow and watershed conditions. Since some streams receive raw or partially treated sewage it may be necessary to properly treat the water before using. Streams are generally high in organic material.

LAKES. Lakes are generally a satisfactory source of water supply. Lakes in warm climates may contain considerable amounts of vegetable or animal organisms. (Many lakes have a high content of dissolved minerals.) Surface waters obtained from lakes are similar to those from flowing streams except considerable self-purification may take place in lakes changing water quality to a large extent.

### Ground Water

Ground water is usually clear, cool and LOW in organic material, but may be HIGH in dissolved mineral content. Excessive withdrawal of ground water near the seacoast may lower the water table allowing infiltration of salt water.

**SPRINGS.** Spring water is generally clear, cool, LOW in organic impurities and is frequently HARD because of a high dissolved mineral content. Heavy infiltration of surface water will cause springs to become turbid.

**SHALLOW WELLS.** Shallow wells normally produce good water of a medium temperature and mineral content but are subject to seasonal fluctuation, contamination and pollution.

**DEEP WELLS.** Deep wells are less subject to seasonal fluctuation, contamination an pollution than shallow wells. They normally produce cool water of HIGH mineral content.

## Seawater

Distillation equipment may be used to produce usable water from brackish water, seawater or other waters containing excessive amounts of dissolved solids. This type of water supply is normally used only in emergencies or where no suitable surface or ground water source is available.

## Collected Water

Water may be collected from roofs or from specially constructed drainage sheds. This method is not favored where surface or ground water sources may be easily developed. However, roof drainage has been used as the main source of water supply for large populations in semiarid regions and in the tropics where rainfall is heavy but available surface waters are highly polluted.

## CHARACTERISTICS OF WATER

### Suspended Impurities and Their Effects

**TURBIDITY.** Turbidity is the term applied to suspended matter of any nature present in a water supply. A distinction is sometimes made between suspended matter which settles rapidly and that which settles slowly, the former being called "sediment" and the latter "turbidity". Usually, however, all forms of suspended matter are grouped together under one term "turbidity". Turbidity, when present as a dirty sediment, is objectionable for practically all uses. This has led to certain standards of tolerance. In the United States Public Health Service drinking water standards for drinking and culinary water supplied by common carriers in Interstate Commerce, it is stated that turbidity shall not exceed 10 ppm (silica scale). Turbidity is expressed in an analysis as silica and imparts an unsightly appearance to water. Turbidity also leaves deposits of sediment in water lines, cooling system and boilers, and thereby interferes with industry processes.

**ORGANISMS.** Although some organisms found in water cause disease when consumed, we are mainly concerned with their effect on mechanical equipment. Normally, organisms in a water supply are not significant.

**ALGAE.** A concentration of algae in water will cause taste, odor, color and turbidity. Except only in extreme cases will we be concerned with other than the latter two. Turbidity will have to be removed by filtration or sedimentation with or without the aid of chemicals.

### Dissolved Impurities and Their Effects

The amount of dissolved minerals in water depends on the length of time the water is in contact with the minerals. When ground water is in contact with minerals for a long period of time, it will often contain one or more of the following.

**HARDNESS.** Minerals or salts present in the feedwater in dilute form become concentrated in the boiler water. The slightly soluble minerals can therefore deposit or precipitate out of the boiler water. They may come out in the form of a scale on the boiler metal surface or in the form of a sludge throughout the body of the boiler water.

**ALKALINITY.** Caused by the presence of bicarbonate ($HCO_3$), carbonate ($CO_3$) and hydroxide (OH). The effect of these compounds is foaming and carryover of solids with steam and embrittlement of boiler steel. When heated, carbonate and bicarbonate will liberate $CO_2$ (carbon dioxide).

FREE MINERAL ACID. Sulfuric, hydrochloric, etc., acids that occur naturally in water will cause corrosion.

CARBON DIOXIDE. Causes corrosion in water lines and, particularly, steam and condensate lines.

SULFATE ($SO_4$). Adds to solids content of water but, in itself, is not usually significant. Combines with calcium to form calcium sulfate scale.

IRON. Discolors water when precipitated. Source of deposits in water lines and boilers.

OXYGEN (O). Dissolved oxygen when liberated causes corrosion of water lines, heat exchange equipment, boilers, return lines, etc. (Called pitting.)

HYDROGEN SULFIDE ($H_2S$). Causes corrosion.

AMMONIA ($NH_3$). Causes corrosion of copper and zinc alloys.

Table 1 summarizes some common impurities in water. Constituents, chemical formulas and the difficulties will be further discussed in the following sections of this study guide.

| CONSTITUENT | CHEMICAL FORMULA | DIFFICULTIES CAUSED | MEANS OF TREATMENT |
|---|---|---|---|
| Turbidity | None-expressed in analysis as units. | Imparts unsightly appearance to water. Deposits in water lines, process equipment, boilers, etc. Interferes with most process uses. | Coagulation, settling and filtration. |
| Color | None--expressed in analysis as "units" of color on arbitrary scale. | May cause foaming in boilers. Hinders precipitation methods such as iron removal, hot phosphate softening. Can stain product in process use. | Coagulation and filtration. Chlorination. Absorption by activated carbon. |
| Hardness | Calcium and magnesium salts expressed as $CaCO_3$. | Chief source of scale in heat exchange equipment, boilers, pipe lines, etc. | Softening. Distillation Internal boiler water treatment. Surface active agents. |
| Alkalinity | Bicarbonate ($HCO_3$) carbonate ($CO_3$) and hydroxide (OH) expressed as $CaCO_3$. | Foaming and carryover of solids with steam. Embrittlement of boiler steel. Bicarbonate and carbonate produce $CO_2$ in steam, a source of corrosion. | Lime and lime-soda softening. Acid treatment. Hydrogen zeolite softening. Demineralization. Dealkalization by anion exchange. Distillation. |

Table 1. Common Impurities in Water

| CONSTITUENT | CHEMICAL FORMULA | DIFFICULTIES CAUSED | MEANS OF TREATMENT |
|---|---|---|---|
| Free Mineral Acid | $H_2SO_4$, HCl, etc. | Corrosion. | Neutralization with alkalies. |
| Carbon Dioxide | $CO_2$<br>of color on arbitrary scale. | Corrosion in water lines and particularly steam and condensate lines. | Ae-ation. Dearation. Neutralization with alkalies. Filming and neutralizing amines. |
| Iron | Fe --- (ferrous)<br>Fe --- (ferric) | Discolors water on precipitation. Source of deposits in water lines, boilers, etc. | Aeration. Coagulation and filtration. Lime sofening. Cation exchange. Contact filtration. Surface active agents for iron retention. |
| Oil | Expressed as oil or other extractible | Scale, sludge and foaming in boilers. Impedes heat exchange. Undesirable in most processes. | Baffle separators. Strainers, coagulation and filtration. Diatomaceous earth filtration. |
| Oxygen | O | Corrosion of water lines, heat exchange equipment, boilers, return lines, etc. | Deaeration, sodium sulfite. Corrosion inhibitors. |

Table 1. Common Impurities in Water (Continued)

## Effects of Impurities in Water

CARRYOVER. Carryover is a word used to express what happens in a boiler when water is entrained by (carried over with) the steam. The amount of water that may be tolerated in steam depends upon its use. The steam contains some water from the bits and pieces of bursting bubbles. This small amount usually does not cause trouble in a heating system. Modern boiler construction usually provides for removing most of the water before the steam enters the distribution system. However, care must be taken that the water level is not so high that carryover actions take place under conditions of swinging load. High concentration of hydroxide (causticity), phosphate and other dissolved and suspended solids also may aggravate carryover.

FOAMING. Foaming is one cause of carryover. It is the production of froth or unbroken bubbles on the surface of the boiler water. The froth may be thin with a few bubbles overlying each other or it may build up and fill the steam space. Froth is close to steam in density, and it is difficult to separate the two. The moisture content of the steam increases under such conditions, and it carries a large load of impurities. The formation of froth depends on the roughness of the films that contain the steam in bubbles. An exceptionally tough film will not break easily to release the steam. One common cause of frothing is soap that enters the boiler from outside sources or is formed within the boiler from oils or animal greases in the feedwater. Foaming may also result from combinations of finely divided solids in suspension together with a high concentration of salts in solution. (See figure 1.)

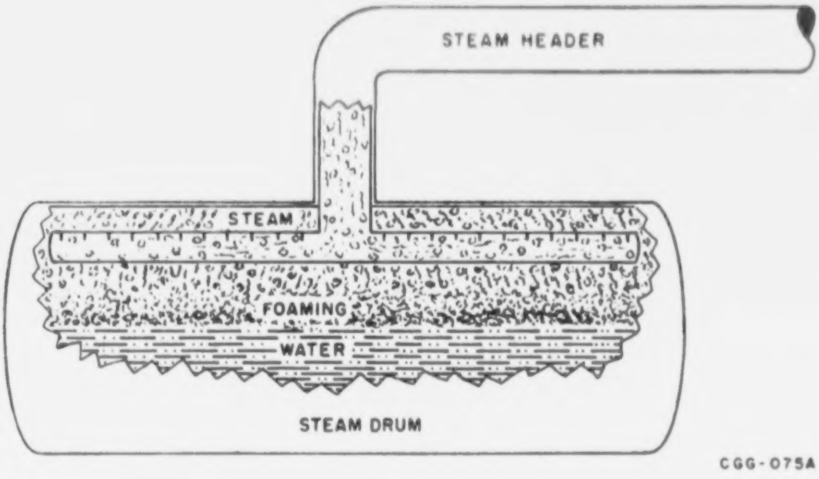

STEAM HEADER
STEAM
FOAMING
WATER
STEAM DRUM
CGG-075A

Figure 1. Foaming

PRIMING. Priming is another cause of carryover. It is an action in which slugs of water are thrown into the steam space. Even pure water may become superheated and suddenly turn to steam. The force tears chunks of water from the boiler-water surface. One common cause of superheated water is a sudden change in load. The breaking away of particles of scale may cause priming from sudden local steaming of superheated water. Smaller slugs of water may be carried from the surface when the steaming rate is too high. (See figure 2.)

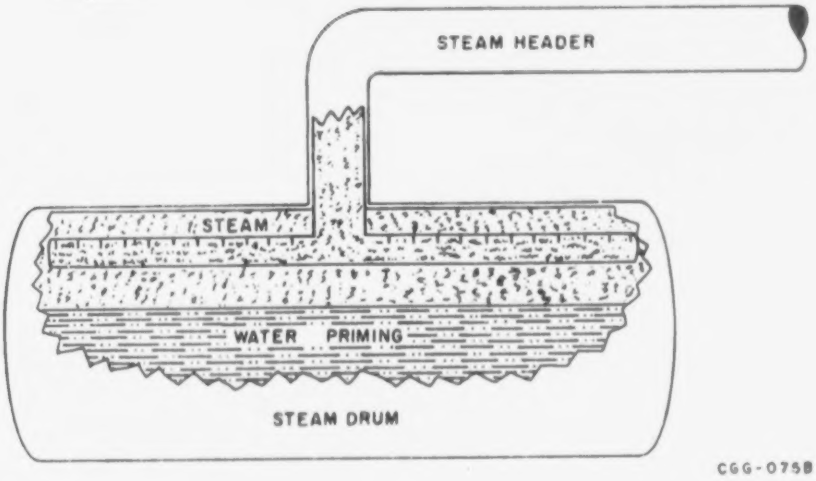

STEAM HEADER
STEAM
WATER
PRIMING
STEAM DRUM
CGG-075B

Figure 2. Priming

**CAUSTIC BOILER-SEAM CRACKING.** Caustic boiler-seam cracking (once called "caustic embrittlement") results from the action of very alkaline water on the boiler stel in riveted seams and at boiler-tube ends. Since the cracks form in seams where they are not easily seen, it helps that most of the time such cracks spread slowly and the seams leak to give warning before they fail. Explosions have occurred where this leakage warning was disregarded, and nearby people were killed.

The corrosion action is of a special kind. Steel is made up of a large number of single crystals or grains of metal, with boundaries where each crystal joins the next one. The layer or film of black iron oxide over a boundary behaves a little differently to some chemicals than the oxide over the grains. For example, the layer over a boundary can be penetrated by a hot, concentrated solution of sodium hydroxide. This lets the hot hydroxide get at the boundary itself. Since there are small electrical differences between the boundary metal and the oxide over the grains, cells may be set up to start corrosion. The steel may be under high stress for much action to take place, but corrosion between grains can happen at a lively rate if everything is just right. Cracks form when the corrosion goes deep enough, and this increases the speed of the process. Failure occurs when the unsound steel no longer can carry the load.

The boiler water cannot corrode steel in this manner. It does not carry a high enough concentration of sodium hydroxide. But boiler water can seep into seams. If there is a slight steam leak from the seam, the sodium hydroxide in solution will be left in the seam to concentrate. This process has been shown to produce very high concentration of the hydroxide, high enough to cause corrosion and cracking.

The steel in seams is usually stressed by riveting or rolling (tube ends). Thus, caustic cracking can happen if hot concentration sodium hydroxide is formed in such a seam. However, this special kind of cracking should not be confused with other types, such as "fatigue" failures that are caused by alternated stress and "creep" failures that are caused by overheating. (See figure 3.)

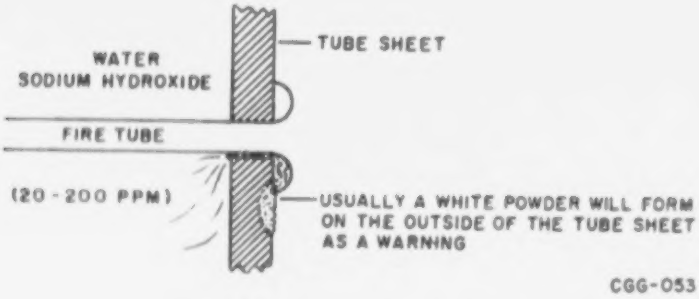

TUBE SHEET
WATER
SODIUM HYDROXIDE
FIRE TUBE
(20 - 200 PPM)
USUALLY A WHITE POWDER WILL FORM ON THE OUTSIDE OF THE TUBE SHEET AS A WARNING
CGG-053

Figure 3. Seam Fatigue

### Effects of Increasing Makeup Water Rate

Makeup water brings the impurities we have discussed previously into the boiler. Thus it is logical that, if more impurities are brought into the boiler, there will be more treatment required. The more you have to treat the boiler the greater the cost of maintaining proper chemical concentrations, plus losses in efficiency and man-hours for treatment.

Major Contributors to Hardness

Hardness in water is undesirable because the effects can be costly and dangerous to boiler operation. Hardness is caused by calcium and/or magnesium salts dissolved in water. In many cases, it is usually easier to dissolve a substance in hot water; however, just the opposite is true in regards to hardness. The dissolved minerals which cause hardness will "fall-out" or precipitate from the boiling water as it is heated and the pressure increases. This precipitate which "falls-out" often forms scale on boiler tubes and acts as an insulator. The heat transfer of the boiler drops and fuel consumption rises. The boiler efficiency is greatly reduced.

A precipitate may take the form of an adherent scale or sludge. Sludge, unless kept fluid and removed with blowdown, may settle on metal and bake to an adherent scale. As adherent scale forms, it may collect sludge particles suspended in the boiler water, including iron rust and sand. Thus, scales may include a mixture of minerals and vary a great deal in composition.

The salts in boiler water do not have an entirely independent existence. The amounts of each salt in solution and the interactions of the many ions follow definite laws and must always be in balance. The addition or removal of ions or salts disturbs the balance and leads to a new balance formed sometimes quickly, sometimes slowly.

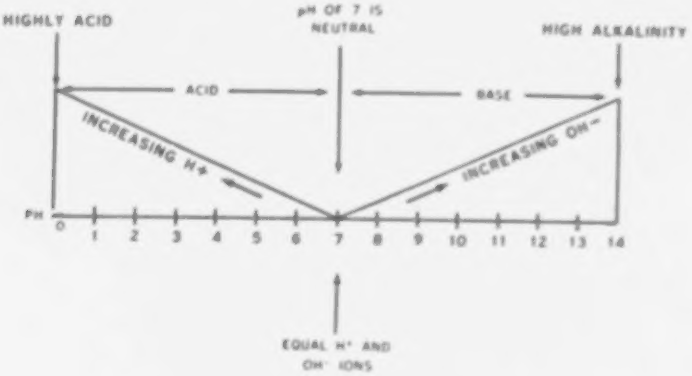
Hardness of water is noticeable in the home and laundries because it forms a scum with soap and reduces formation of soap lather.

## POTENTIAL HYDROGEN SCALE

Definition of pH is the logarithm of the reciprocal of hydrogen-ion concentration. It is also a number between 0 and 14 indicating degree of acidity or alkalinity. The pH scale resembles a thermometer or hydrometer scale. Just as the thermometer measures intensity of heat and a hydrometer the density of a solution, the pH scale indicates intensity of acidity or alkalinity, see figure 4.

Midpoint of the pH scale is 7 and a solution with this pH is neutral. Numbers below 7 denote acidity; those above alkalinity. Since pH is a logarithmic function, solutions having a pH of 6.0, 5.0 and 4.0 are 10, 100 and 1000 times more acid than one with pH of 7.0.

Now let's apply this to water chemistry. In addition to molecules of $H_2O$, pure water contains separated parts of molecules called hydrogen ions and hydroxide ions. Amounts of dissociation is constant at any given temperature. At 25°C, the product of the H+ and OH- concentrations is 1 X 10-14. When hydrogen-ion concentration changes, the hydroxide ion concntration changes in proportion and always in the opposite direction. If the H+ ions decrease, the OH = ions increase enough so product of the two concentrations at 25°F remains 1 X 10-14. The exponent -14 is the basis of the pH scale, a method of expressing hydrogen-ion concentration in terms of a negative logarithm to the base 10.



Figuare 4. Potential Hydrogen Scale

Acid or alkaline nature of a solution depends on whether hydrogen or hydroxide ions predominate. Ionic theory is that salts, acids and bases are torn apart by water molecules to form positively or negatively charged fragments called ions. When acids are mixed with water, hydrogen-ion is one result of the breakup.

In a mixture of bases and water, hydroxide ions result. Hydrogen-ions make a solution acid; hydroxide-ions tend to make it alkaline. When the solution contains one OH ion for every H ion, acid effect of one balances the alkaline effect of the other. Result is a neutral solution with a pH of 7.0.

## MAJOR CONTRIBUTORS TO CORROSION

### Oxygen

Consider two identical boilers installed at the same time -- one has a tube to fail within one year, while the other operates constantly for ten years without a single tube failure. What is the reason for the great difference? Is it a discrepancy in tube quality? Possible, but the most probable reason is corrosion. Corrison is generally caused by improper operating and maintenance procedures. Almost all quick corrosion failures can be traced to conditions of tube environment. Oxygen and the degree of alkalinity are the mechanisms which causes pitting and is the most common form of waterside corrosion.

In slightly acid or slightly alkaline solutions, pitting takes place at a rate which depends on the amount of oxygen present in the water. In strong acid solutions, steel corrodes uniformly without pitting. Cold water can hold more air than warm water. The bubbles of air that forms as a boiler begins to heat up are very destructive to boiler tubes. This "bubble pitting" is caused by relatively higher oxygen concentration in the water. Therefore, as much air as possible must be removed from the boiler water for corrosion-free operation.

### Carbon Dioxide

Corrosion in condensate return lines and associated equipment is a problem at many Air Force bases. The salts and causticity in the boiler water are not volatile and ordinarily only small amounts go over with the steam; therefore, the condensate is generally rather pure water. However, carbon dioxide does go over with the steam and dissolves in the condensate, lowering the pH of return condensate and making it more acid. The carbon dioxide is more corrosive than the oxygen which leaks in at pipe connections. But when both are present, the problem is intensified and a corrosion problem is likely to exist. Acid corrosion usually grooves and channels the bottom of the pipe; frequently, it is more pronounced just beyond the traps of hot-water generators or radiators. Oxygen corrosion normally pits the entire circumference of the pipe.

### SUMMARY

Two general sources of water are surface waters and ground waters. Since water is a universal solvent, many impurities are dissolved or suspended in untreated raw water. The impurities found in water will differ with the different geographical locations.

Surface waters usually contain a high concentration of organic materials such as leaves, silt, vegetable and animal organism; sand is also a major impurity in surface waters.

Ground waters usually contain a high concentration of dissolved minerals, such as calcium and magnesium which give water its hardness characteristics.

The ability of water to corrode or cause scale on the metal surface of the boiler is determined by the concentration of the impurities in the water.

Water containing a high concentration of alkaline could cause caustic embrittlement and scale, while water with a high acid concentration would cause corrosion.

QUESTIONS

1. What are four sources of water?

2. Two examples of surface water are ______________ and ______________.

3. Name three examples of suspended impurities.

4. Alkaline is caused by the presence of ______________________, ____________________ and _______________________.

5. Explain caustic embrittlement.

6. What are the two main contributors that cause hard water?

7. What does 4.5 on the pH scale denote?

8. What are the two main contributors that cause corrosion in boilers and systems?

9. Do dissolved gases found naturally in water have a harmful effect on mechanical equipment?

REFERENCES

1. AFM 85-12, Volume I, Operation and Maintenance of Central Heating Plants and Distribution Systems.
2. AFM 85-31, Industrial Water Treatment.

845

# EXTERNAL TREATMENT

## OBJECTIVES

Given information, determine step-by-step procedures for installation, operation and servicing of external water treatment equipment with 80% accuracy.

Given information and equipment, service and operate demineralizing equipment with instructor assistance.

Using the soap solution and EDTA water testing equipment, test a given water sample for hardness with instructor assistance.

## INTRODUCTION

In nature the forces that cause scale and corrosion are as constantly in action as the sea. Everyone has seen scale and corrosion turn useful structures into crumbling skeletons; productive machines into frozen hulks; automobiles, pipes and boilers into piles of junk. It costs the Air Force millions of dollars each year. It dissipates our resources and the fruits of our labor. It interrupts productions. It causes accidents.

The formation of scale and sludge deposits on boiler heating surfaces is the most serious water problem encountered in steam generation. The object of the majority of the external treatment processes is to remove from the boiler feedwater those objectionable substances which will contribute to scale or deposit formations in the boiler. The primary causes of scale formation is the fact that the solubilities of scale-forming salts decrease with the increases in temperature. The actual mechanism of scale deposition can be viewed as taking place in two distinct operations. First, the precipitation from solution of a salt such as calcium carbonate ($CaCO_3$); and the second, the sedimentation of this already formed precipitate on the boiler heating surfaces where it bakes in place as scale.

Corrosion is the deterioration, or dissolving, of metals by chemical reaction. Moisture and oxygen are always present and are the important factors. For any given corrosion reaction involving the same relative quantities of combining or reacting elements, the rate of corrosion is increased with an increase in temperature. Likewise, increasing or decreasing the amount of oxygen present increases or decreases the rate of corrosion. The conditions causing corrosion are numerous, but the principal causes are dissolved gases, corrosive salts, acidity and electrolytic (galvanic) action.

Different metals are affected to different degrees, and the corrosive attack takes many different forms. Attack may be by general tarnishing or rusting with occasional performations in especially affected areas. Corrosion often develops near the junction of two different metals. The metal may suffer highly localized attack by pitting. The strength of a metal may be destroyed by cracking. We are familiar with corrosion in these ways.

From information above, you can see the importance of this subject to the Air Force. In the near future, the dependability and performance of vital defense equipment may well depend on how skillful you become in scale and corrosion control maintenance.

External treatment for hardness is divided into two general classifications: the ion-exchange methods, which exchange scale-forming compounds of calcium and magnesium for non-scale-forming compounds of sodium or hydrogen; and the precipitation method, which separates the scale-forming materials from the boiler feedwater before it enters the boilers. An example of the former is the zeolite treatment system; of the latter, the lime-soda process.

## OPERATE AND SERVICE DEMINERALIZING EQUIPMENT

### Procedures for Removing Dissolved Impurities

Many of the purposes of boiler water treatment are best achieved by mechanical means, while others may require chemical treatment. The use of feedwater heaters, blowdown, steam washers and evaporators, for instance, is mechanical. Elimination of leaks throughout the plant may achieve many of the aims of boiler water treatment. For example, maintaining a high rate of return water to the boiler decreases the amount of chemical necessary for treating the boiler water. Proper operation of feedwater heaters and venting of gases may give adequate control of corrosion in the feed lines and boiler, and eliminates the need for certain chemical treatment for corrosion control. Good mechanical housekeeping throughout the plant is frequently the first step in eliminating many of the difficulties associated with water conditions. For complete accomplishment of all the aims of boiler-water treatment, it is necessary to combine controlled treatment of chemicals with mechanical treatment and maintenance.

### Chemical Precipitation Process

The process of chemically separating one substance "out" in solid form from a solution. Example: Lime-Soda Softening (Hot and Cold).

LIME-SODA SOFTENING. Lime-soda softening is employed for the removal of hardness in order to minimize scale and sludge in boilers, and to reduce calcium carbonate deposits in heat exchange systems and cooling water systems. Incidental to the removal of hardness, the lime-soda softening process will generally remove iron, free carbon dioxide and turbidity. The treatment process is accomplished by adding lime (calcium hydroxide $Ca\ (OH(_2))$ and soda ash (sodium carbonate $Na_2CO_3$) to the raw water.
This process is carried out at normal raw water temperatures, which is classified as the "cold process" or at temperatures near or above the boiling point, referred to as the "hot process". Lime-soda softening may reduce the hardness to as low as 10 to 30 ppm.

Hot Lime-Soda Softening. Hot lime-soda softeners are all similar in operation. The process is continuous and is carried on at a temperature of 212°F. Live steam or exhaust steam is used as a heat source. Raw water enters the top of the tank, mixes with the chemicals and sprays through the steam. The steam heats and deaerates the incoming mixture. The sludge settles to the bottom of the tank and the clarified water is carried to a deaerating chamber and then out to the filter. An illustation of the sludge-blanket hot process softener is shown in figure 5.

The retention time for this type of softener is about one hour. Usually no coagulant is required unless the incoming water is fairly turbid. The practical limit of turbidity is about 100 ppm. The effluent from this process has a hardness of about 25 ppm or less and is substantially reduced in total dissolved solids, alkalinity, $SiO_2$ and oxygen.

Water is generally filtered after either the hot or cold lime-soda process. After cold lime-soda softening, the water is usually run through a re-carbonation tank before filtering. In this process, carbon dioxide is added to the treated water to prevent further precipitation. This prevents precipitates from clogging the filter bed and from forming scale in distribution lines and boilers. An anthracite filter is used following hot process lime-soda softening. The use of sand is discouraged because the hot effluent would dissolve some silica from the sand.

Hot Process. The hot lime-soda process is well suited for softening water that is used hot. Boiler makeup water pretreatment is the most common application. It is also used for commercial processes, such as paper mills and chemical plants.

In industrial water conditioning, one of the major applications of aeration is in the removal of the corrosive characteristics imparted to water by the presence of carbon dioxide and hydrogen sulfide. On many occasions aeration is used to remove the carbon dioxide liberated by a treatment process. For example, in boiler feedwater conditioning, it is common practice to acid-treat the effluent from a sodium zeolite softener in order to reduce the alkalinity of the boiler feedwater. Carbon dioxide is produced as a result of the acid treatment and aeration is employed to rid the water of this corrosive

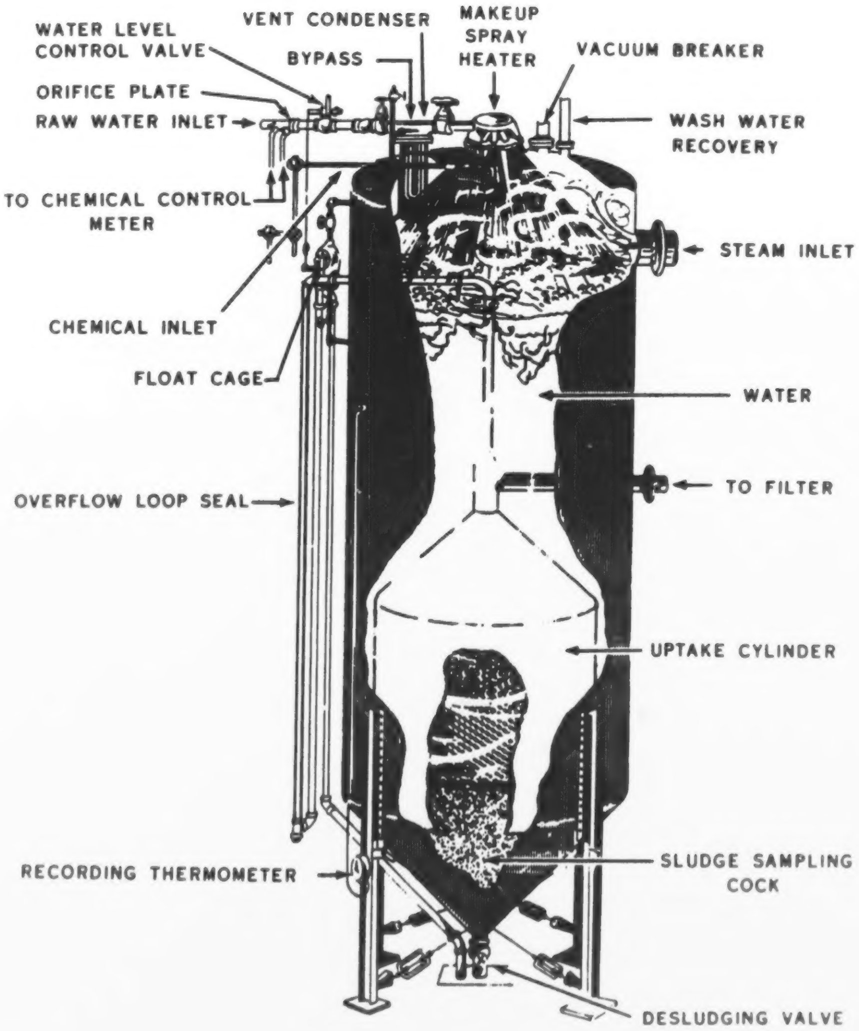

WATER LEVEL CONTROL VALVE
VENT CONDENSER
MAKEUP SPRAY HEATER
VACUUM BREAKER
BYPASS
ORIFICE PLATE
RAW WATER INLET
WASH WATER RECOVERY
TO CHEMICAL CONTROL METER
STEAM INLET
CHEMICAL INLET
FLOAT CAGE
WATER
TO FILTER
OVERFLOW LOOP SEAL
UPTAKE CYLINDER
RECORDING THERMOMETER
SLUDGE SAMPLING COCK
DESLUDGING VALVE
CGK-006

Figure 5. Sludge-Blanket Hot Process Softener

gas. Similarly, when the effluents of hydrogen and sodium zeolite units are blended, the carbon dioxide formed is eliminated by aeration. In anion-cation exchange, aeration is similarly used. Forced draft aerators are usually employed in these applications.

## Ion Exchangers

Softening water is a process in which hardness, caused by calcium and magnesium, is removed from the water. These elements are responsible for most scale and sludge in boilers. Except for special cases, scale prevention is an operation in which something is done about the calcium and magnesium. One of the ways of preventing this scale outside the boiler is called "zeolite softening".

A group of minerals called zeolites, mostly made up of sodium, aluminum, oxygen and silicon, have the property of exchanging their sodium for the calcium or magnesium in the water. When this happens, the sodium goes into the water and the hardness goes into the mineral. This action can be reversed by passing a strong solution of common salt (NaCl) through the bed of zeolite material. A re-exchange then takes place owing to the high concentration of sodium in th brine. This re-exchange, or "regeneration" of the mineral, restores it for reuse -- after the brine is drained off and the zeolites are rinsed. See figure 6.

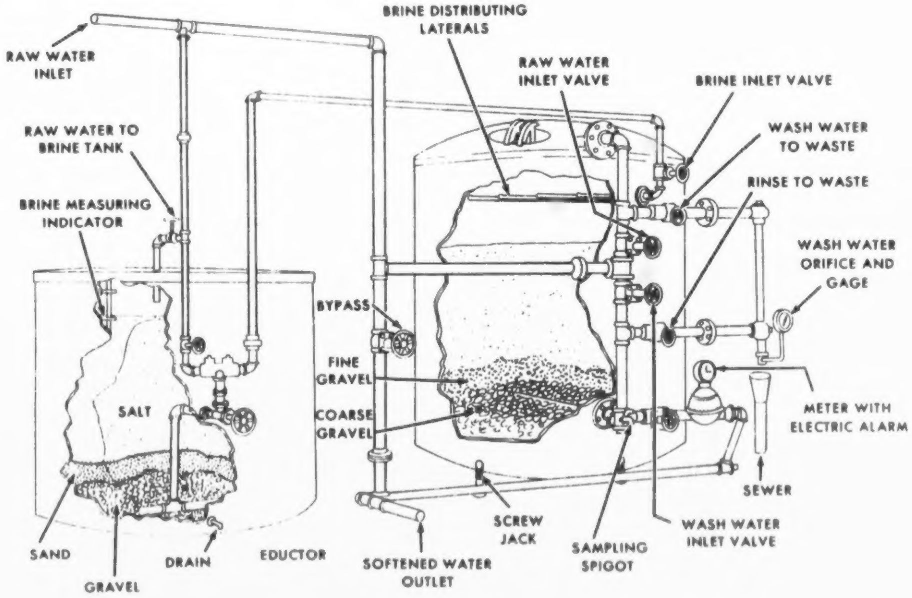

BRINE DISTRIBUTING LATERALS
RAW WATER INLET
RAW WATER INLET VALVE
BRINE INLET VALVE
WASH WATER TO WASTE
RAW WATER TO BRINE TANK
RINSE TO WASTE
BRINE MEASURING INDICATOR
WASH WATER ORIFICE AND GAGE
BYPASS
FINE GRAVEL
SALT
COARSE GRAVEL
METER WITH ELECTRIC ALARM
SEWER
SAND
GRAVEL
DRAIN
EDUCTOR
SOFTENED WATER OUTLET
SCREW JACK
SAMPLING SPIGOT
WASH WATER INLET VALVE

Figure 6. Manually Operated Zeolite Softener

Chemists have duplicated natural zeolites by controlling the union between sodium, aluminum, silicon and oxygen. These synthetic zeolite minerals can be made to specifications so that each cubic foot of material will have a predictable capacity for removing hardness. With a guaranteed synthetic zeolite, the operator can better specify the size of bed he will need for the amount of water he expects to soften before regeneration.

The man-made zeolites are the resinous-type. They have been developed recently and are usually the most satisfactory for industrial water softening. This type consists of a group of polystyrene-base products in the form of small beads. Polystyrene zeolites are endangered only when the pH exceeds 11; however, their danger point as far as water temperature is concerned is 250°F.

NOTE: All zeolites used in the hydrogen acid-cycle have to be watched closely as they near the end of their "run" cycle; over-exhaustion will permanently polarize the bed, destroying it.

Zeolite softening is the use of one of these zeolites in a bed (similar to a filter bed) to remove dissolved calcium and mangesium from water. The bed should be large enough to take the peak rate of flow. The number of hours before regeneration is needed must also be considered. If the water does not differ much in hardness, regeneration can be scheduled by reading the water meter. Otherwise, the water coming from the softener is tested, and the bed is regenerated when it begins to let hardness through. The regenerating brine, together with the extracted calcium and magnesium is run to waste, and the bed is reusable after rinsing. Regeneration may take an hour or more. The operator who has two beds can switch from one to the other and always have one he can use.

Choosing the right zeolite is important. Silicate zeolites vary widely in exchange capacity, speed of regeneration, durability and general performance characteristics. Some are dense and heavy, and others are porous and light. High rated zeolites may lose much of their exchange capacity after a few regenerations. They may even become mushy and have to be replaced. Purchase specifications should be written very carefully, and the purchased zeolite should be guaranteed.

The material should be chosen for the intended use. Silicate zeolites are broken down by acid or alkaline water; the safe pH range is reported to be from 6.2 to 8. The water to the bed should not be warmer than about 100°F. It is not good to use a zeolite bed as a filter since suspended solids such as clays, ferric hydroxide or calcium carbonate clog the pores of the mineral and destroy capacity.

The raw water flows downward through the zeolite bed at a flow rate of 5 to 6 gallons per minute per square foot of area, and the softened water then collects in the underdrain system. The softening process continues until the zeolite bed is exhausted and regeneration is in order. The length of time between regenerations can be determined by knowing how much hardness your water contains and how much hardness the zeolite will remove.

The regeneration solutions for sodium cation exchangers is usually about a 10 percent solution of common salt. It is injected at the rate of 3/4 gallons per cubic foot of zeolite per minute. The amount of salt used for regeneration determines the exchange capacity of the zeolite bed within the limits of the particular zeolite used. For a polystyrene exchange material, the amount of salt used is within the range of 0.25 to 0.45 pounds per 100 grains of hardness removed. The salt dosage can be adjusted for variations in the hardness of the raw water.

Sulfuric acid is used as a regenerant for polystyrene cation exchangers on the hydrogen cycle. About 4 pounds of sulfuric acid per cubic foot will give the zeolite a capacity of about 12,000 grains per cubic foot. If sulfuric acid is used, it must be started in a low concentration, about two percent solution, and increased in steps up to an eight percent solution to prevent calcium sulphate from precipitating and clogging the bed. Follow the recommendation of the manufacturer.

HYDROGEN ZEOLITE. Use this acid-cycle softener when necessry to reduce alkalinity and soften the water simultaneously (reduce the bicarbonate and carbonate alkalinity). Then the effluent is neutralized by blending it with effluent from a sodium-cycle softener, an alkali solution, or raw water of low hardness and high alkalinity.

The softened effluent has a high carbon dioxide content and is very corrosive when it is first blended; therefore, it must be degasified. This is accomplished with a wooden degasifier installed just ahead of the feedwater heater. Since the degasifying operation aerates the water highly, particular attention must be given to removing oxygen from feedwater before it enters the boilers. See Figure 7.

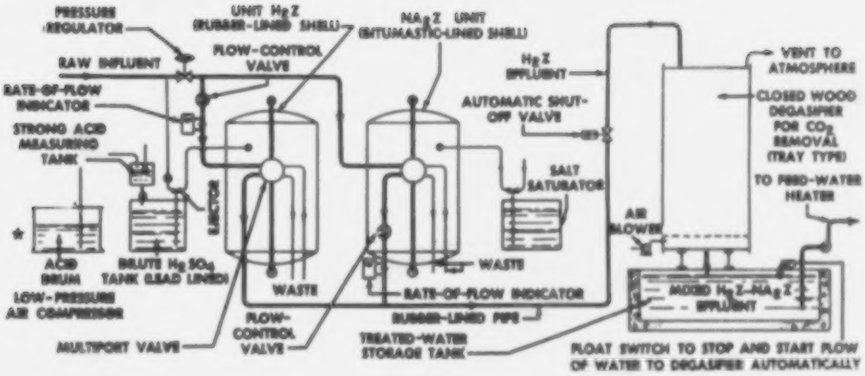

PRESSURE REGULATOR
UNIT $H_2Z$ (RUBBER-LINED SHELL)
$NA_2Z$ UNIT (BITUMASTIC-LINED SHELL)
RAW INFLUENT
FLOW-CONTROL VALVE
RATE-OF-FLOW INDICATOR
STRONG ACID MEASURING TANK
EJECTOR
$H_2Z$ EFFLUENT
AUTOMATIC SHUT-OFF VALVE
VENT TO ATMOSPHERE
CLOSED WOOD DEGASIFIER FOR $CO_2$ REMOVAL (TRAY TYPE)
TO FEED-WATER HEATER
SALT SATURATOR
AIR BLOWER
*
ACID DRUM
DILUTE $H_2SO_4$ TANK (LEAD LINED)
LOW-PRESSURE AIR COMPRESSOR
WASTE
WASTE
RATE-OF-FLOW INDICATOR
MIXED $H_2Z$-$NA_2Z$ EFFLUENT
RUBBER-LINED PIPE
MULTIPORT VALVE
FLOW-CONTROL VALVE
TREATED-WATER STORAGE TANK
FLOAT SWITCH TO STOP AND START FLOW OF WATER TO DEGASIFIER AUTOMATICALLY

Figure 7. Flow Diagram of Hydrogen and Sodium Combined Effluent System (Ion Exchange Demineralizing Process)

# OPERATING AND SERVICING ZEOLITE SOFTENERS
# (ION EXCHANGERS)

When the zeolite water softener is in opertion, water passes down through the zeolite where ION EXCHANGERS take place. The water is softened and continues on to the boiler or wherever the softened water is to be used. This process continues until the zeolite becomes exhausted and no longer softens water. This is determined by a water hardness test.

When the zeolite becomes exhausted, it no longer has an exchange capability. All the sodium or hydrogen ions are gone an the zeolite is saturated or filled with calcium and magnesium.

You have learned the softener is no longer softening water. This doesn't mean the zeolite is not good. It only means the sodium or hydrogen ions are gone from the zeolite. The ions can be put back by a process we call "regeneration", at which time the unit is secured so as to NOT allow any hard water to go to the boiler.

Before regenerating the zeolite water softeners, you must check the concentration of the regeneration solution. Brine (salt water) is used as the regenerate for the sodium zeolite ion exchanger. Hydrochloric or sulfuric acid and water is used with the hydrogen zeolite as a regenerte. A hydrometer is used to check the concentration of salt in the brine solution. It works on the theory of specific gravity. When allowed to float freely in the solution, a reading can be obtained by observing the point on the Baume scale which is parallel to the surface of the solution. This Baume gravity reading times 4 equals the approximate percent of saturation.

To determine the concentration of acid for the hydrogen zeolite softener, you would use a hydrometer designed for the particular acid you are using.

There are three steps or cycles of regeneration called: (1) backwash, (2) regeneration, and (3) rinse. Each manufacturer has his own recommendations and specifications for each regenerating cycle, and we must comply for proper operation; but, the principles of operation are the same and must be followed in order.

(1) BACKWASH - When we backwash the zeolite bed, we do just as the name of the cycle implies. We run the flow of water backwarde, up through the zeolite to wash the zeolite free of any sediment or dirt and regrade the bed to remove any channels that may have developed. All backwash water goes down the drain.

(2) REGENERATION - The regeneration cycle is when the zeolite bed is brought back to life or given back its softening capability. This is done by passing a solution of sodium or hydrogen through the zeolite bed to remove the calcium and magnesium from the zeolite. Sodium or hydrogen take their place by ION EXCHANGE. All the calcium and magnesium that comes off the zeolite will go down the drain.

(3) RINSE - Here again we are doing just as the name of the cycle says, we are "RINSING" the excess regeneration solution from the zeolite bed to prevent it from going into our boilers. The rinse water also goes down the drain.

Regeneration is now complete and the water softener can be placed back in service to produce soft water for our equipment.

Ion exchangers are designed much the same as filters. They may operate either by gravity flow or under pressure. The pressure type is the one most commonly used for industrial water softening because of the smaller space requirements and lower installation cost. Figure 8 shows a typical design. The zeolite bed is supported by a bed of graded quartz gravel about 12 inches deep. The zeolite bed should be at least 30 inches deep and the headroom should be at least 50 percent of the depth of zeolite.

Servicing

Follow manufacturer's specifications.

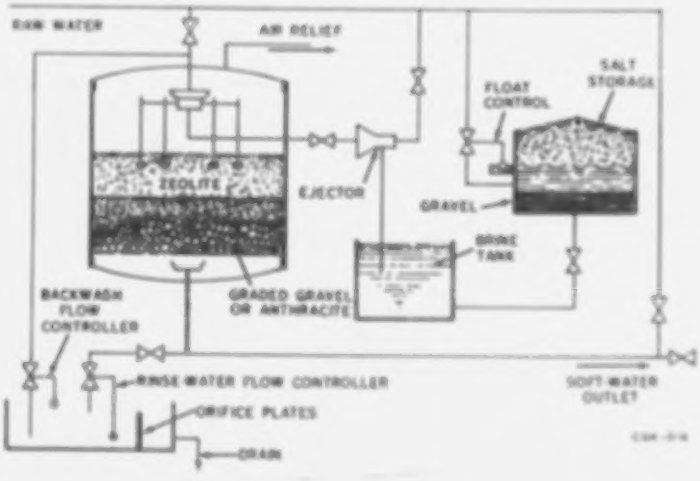

RAW WATER
AIR RELIEF
SALT STORAGE
FLOAT CONTROL
ZEOLITE
EJECTOR
GRAVEL
BRINE TANK
BACKWASH FLOW CONTROLLER
GRADED GRAVEL OR ANTHRACITE
RINSE WATER FLOW CONTROLLER
ORIFICE PLATES
DRAIN
SOFT WATER OUTLET

Figure 8. Typical Zeolite Softener

Brine Test

The brine test is used to determine the brine solution concentration to insure proper regeneration of the sodium zeolite softener.

---- Fill the cylinder with the brine solution to be tested (brine to be obtained or drawn from the brine tank).

---- Place the hydrometer in the brine solution and allow to stabilize.

---- The degree of Baume gravity of the solution is obtained from the stem reading at the point where the surface of the brine touches the stem.

---- The brine should test 24.6° Baume gravity. This represents 100 percent saturation.

NOTE: Braume gravity reading times four equals approximate percent of saturation.

Degassing Equipment

Carbon dioxide will be formed whenever ion exchange, direct acid treatment or chemical precipitation is used to remove impurities from water. To neutralize this formation of $CO_2$, some method of degassing the water must be used. The two most common methods are: aeration and deaeration.

AERATION

Aeration consists essentially of exposing as much water surface as possible to the air. During aeration, gases dissolved in the water supply are released to the atmosphere; soluble iron salts are oxidized and become insoluble so they can be removed by settling. Aeration rises the pH by eliminating dissolved carbon dioxide but increases corrosiveness by increasing the amount of dissolved oxygen. Types of aerators consist of overflowing trays or trays containing slats or coke over which the water is sprayed (figure 9). Other methods of aeration include spraying water up over a shallow receiving basin, and forcing air into a basin with diffusers or mechanical pump type aerators similar to those used in sewage treatment. Operation of most aerators is practically automatic; operators' duties consist essentially of making sure pipes, slots and surfaces are not clogged and that air has free access to the water. If the water is not to be filtered after aeration, aerators must be screened with fine screen to keep out insects and other foreign matter.

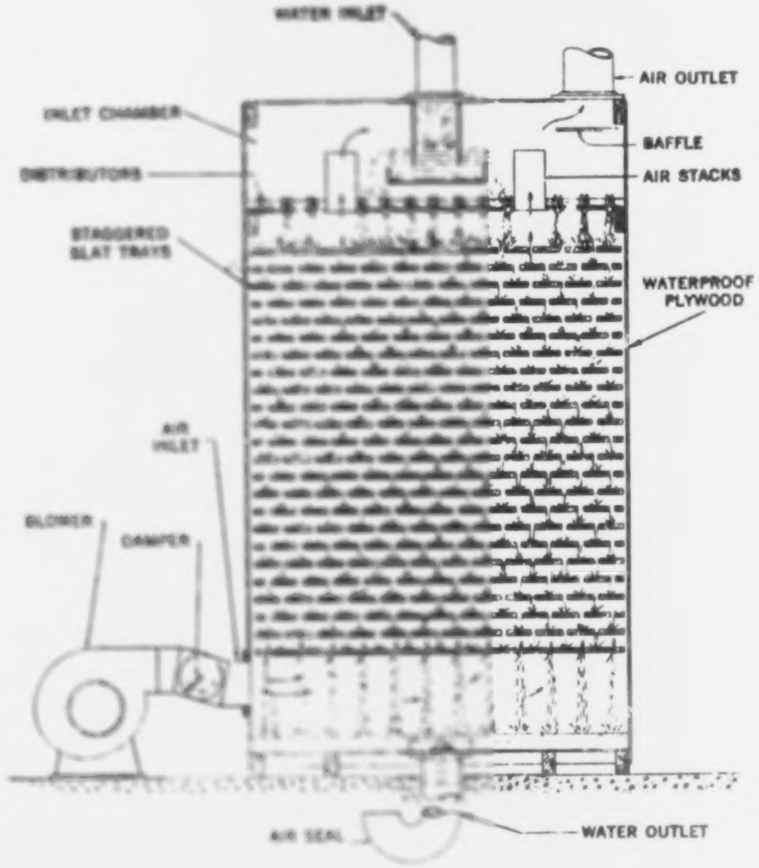


Figure 9. Forced Draft Aerator (Tray Type)

## DEAERATION

Mechanical deaeration, pertaining to boiler feedwater treatment, is the removal of dissolved gases such as oxygen, carbon dioxide and ammonia by the process of raising the water to the saturation temperature for the pressure under which the process is conducted.

TYPES OF DEAERATING EQUIPMENT. The Heat Exchange Institute uses the amount of oxygen removed from feedwater to differentiate between open heaters, deaerating heaters and deaerators. According to their standards, open heaters should remove all oxygen above 0.20 cc (cubic centimeters) per liter; deaerating heaters, all in excess of 0.03 ml (milliliter) per liter; and deaerators, all in excess of 0.005 ml per liter. (A normal guarantee of "less than 0.005 ml per liter of oxygen" means less than seven pounds of oxygen in a billion pounds of water.)

PRINCIPLES OF OPERATION. In the removal of oxygen from water, 90 to 95 percent of the initial free oxygen content can be removed when the water is heated to the saturation temperatue for the pressure imposed on the system. The remaining 5 to 10 percent of the oxygen (Free $O_2$) content can be removed through molecular diffusion or scrubbing.

In accordance with the basic principles contained in the laws applicable to behavior of gases, removal of a dissolved gas from water can be effected by reducing the partial pressure of that gas in the surrounding atmosphere, egardless of the total pressure on teh system. The simplest manner in which this can be accomplished is to bubble another gas through the water or to spray the water into a countercurrent flow of the gas (molecular diffusion), while providing for free venting of the gas from the system.

Exhaust steam from other plant equipment is often used to bring the feedwater to its saturation point for deaeration.

Oxygen can be removed from water by passing another gas counterflow to falling streams of water. Air could not be used for this purpose because of its high oxygen content. Nitrogen could be employed, but the cost would make the process impracticable. The most practical method of removing dissolved oxygen from boiler feedwater is by using a readily available gas, to perform this molecular diffusion. Steam is ideal for this purpose as the thermodynamic principles of steam can be used to raise the water to its saturation temperature. The process of deaeration using the scrubbing action of steam, is usually accomplished through one of the following methods.

Tray Deaerating Heater. Figure 10 illustrates a tray-type deaerating heater. In operation, water passes through the vent condenser, enters the spray distributor and is sprayed upward. The water breaks into small droplets and comes into intimate contact with the steam in that section. The bulb of the noncondensable gases is liberated there and the water is heated almost to steam temperature. Cascading through heating and air-separating traps, the water reaches the temperature of the saturated steam corresponding to the pressure in the unit, and the gases are completely liberated. The deaerated water then passes from the tray section into the storage reservoir. A nearly constant water level is maintained by float-operated valves, which admit water in proportion to the demand. The steam enters through a nozzle in the side of the shell, flows through performations in the top plate of the tray section, and meets the water sprayed upwards from the distributor. Here, most of the steam is condensed. After passing through the tray stack, the remaining steam and the noncondensable gases enter the vent condenser. Here the gases are dischargd to the atmosphere, and the steam is condensed and drained back into the unit.

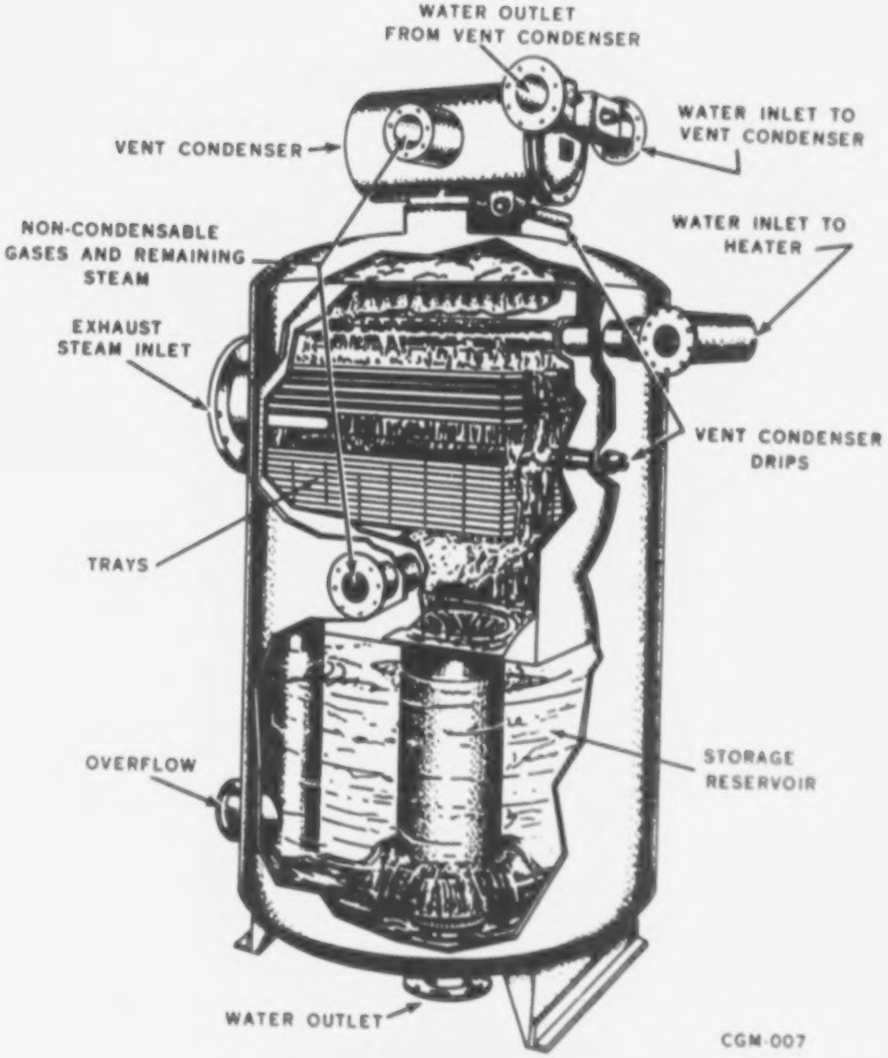

WATER OUTLET
FROM VENT CONDENSER
VENT CONDENSER
WATER INLET TO
VENT CONDENSER
NON-CONDENSABLE
GASES AND REMAINING
STEAM
WATER INLET TO
HEATER
EXHAUST
STEAM INLET
VENT CONDENSER
DRIPS
TRAYS
OVERFLOW
STORAGE
RESERVOIR
WATER OUTLET
CGM-007

Figure 10. A Tray-Type Deaerating Heater

**Spray Deaerating Heater.** Figure 11 illustrates a spray deaerating heater. In this unit, spray valves break up the water instead of cascading it through trays. The preheated water is scrubbed by the entering steam and heated to saturation temperature, and the gases are liberated. The vent condenser (see figure 11) usually consists of a shell and a head with a removable bundle of U-tubes expanded into a tube sheet. The incoming cold water circulates through the tubes, and the condensed steam drains back to the heater.

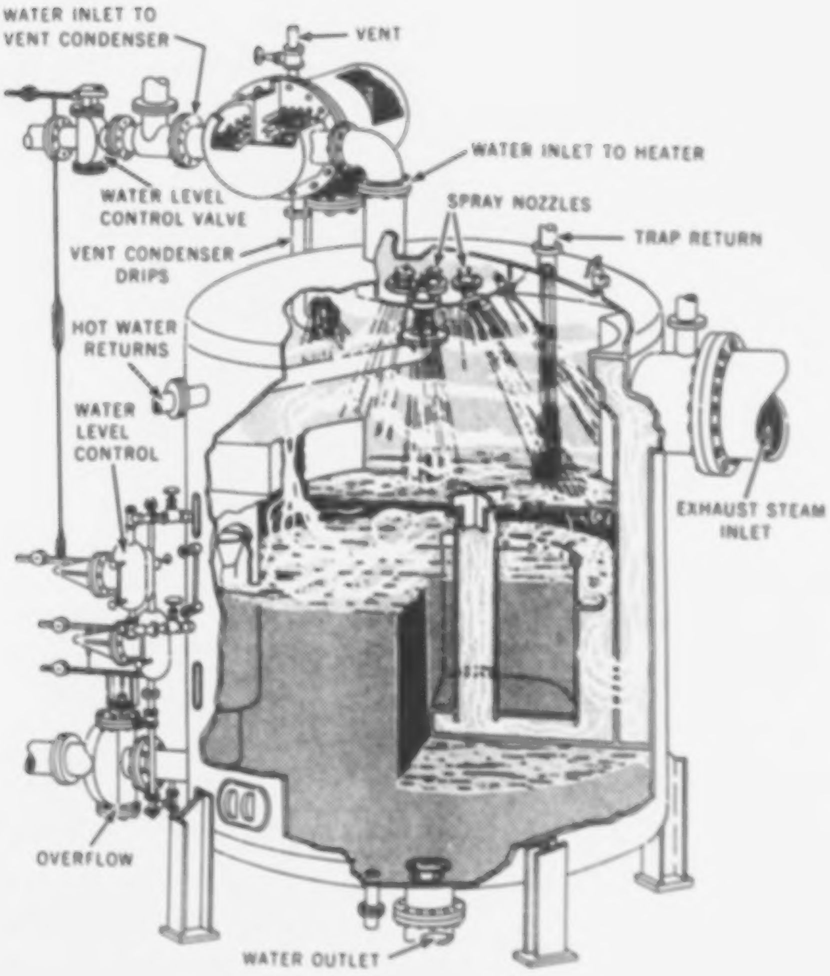

WATER INLET TO VENT CONDENSER
VENT
WATER INLET TO HEATER
SPRAY NOZZLES
TRAP RETURN
WATER LEVEL CONTROL VALVE
VENT CONDENSER DRIPS
HOT WATER RETURNS
WATER LEVEL CONTROL
EXHAUST STEAM INLET
OVERFLOW
WATER OUTLET

Figure 11. Spray-Type Deaerating Heater

Spray Open Heater. In figure 12, a spray open heater is shown. This heater heats the water to within 3° or 4° of steam temperature by spraying it through steam. It does not use the steam scrubber employed in the deaerating heater illustrated in figure 11. This heater reduces the oxygen to less than 0.30 cc per liter.

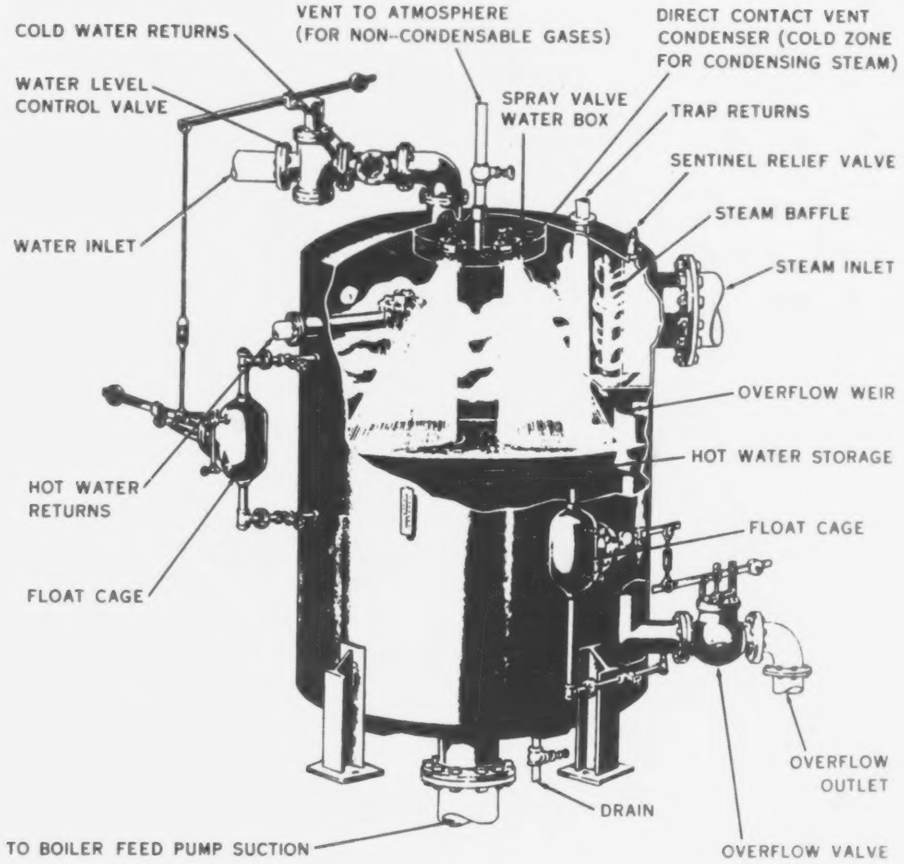

COLD WATER RETURNS
VENT TO ATMOSPHERE (FOR NON-CONDENSABLE GASES)
DIRECT CONTACT VENT CONDENSER (COLD ZONE FOR CONDENSING STEAM)
WATER LEVEL CONTROL VALVE
SPRAY VALVE WATER BOX
TRAP RETURNS
SENTINEL RELIEF VALVE
WATER INLET
STEAM BAFFLE
STEAM INLET
OVERFLOW WEIR
HOT WATER STORAGE
HOT WATER RETURNS
FLOAT CAGE
FLOAT CAGE
OVERFLOW OUTLET
DRAIN
TO BOILER FEED PUMP SUCTION
OVERFLOW VALVE

Figure 12. A Spray Open Heater

### Service Instructions for Deaerating Equipment

Annually clean the deaerating equipment to remove dirt, scale, rust and other impurities from inside the equipment.

- --- Check all valves for proper operation.
- --- Check pressure gauges.
- --- Check and clean temperature gauges.
- --- Check and clean the steam nozzles and repair as needed.
- --- Repair and clean trays as needed.
- --- Replace any fittings which are corroded.
- --- Place all parts and equipment back in deaerating equipment after inspection or repair IAW manufacturer's instructions.

### Deaerating Heater Test

The accurate way to check the performance of a deaerating feedwater heater is to find out how much dissolved oxygen is left in the deaerated feedwater. Most federal heating plants are not equipped to run this test, but a simple color test is usually available to operators.

An efficiently operated deaerating heater will remove nearly all the dissolved gas from the feedwater. This includes the free carbon dioxide in addition to the oxygen. Also, part of the carbon dioxide in the makeup water alkalinity is given up to the steam in the heater and is vented with uncondensed gases.

Most feedwaters, before deaeration, contain bicarbonates but no carbonates. The pH of such feedwater will rise during good deaertion. Removing part of the carbon dioxide from a bicarbonate changes it to a carbonate, which is more caustic. Carbonate in feedwater turns phenolophthalein indicator red because of this causticity. Well-deaerated feedwater is given a very distinct pink color when phenolphthalein indicator is added.

To make sure that you can use this test in your plant, add one part of your makeup water to about four parts of condensate in a 100-milliliter breaker and see if three drops of phenolphthalein indicator turns the mixture red. This test cannot be used in the very few cases where the pH of the feedwater is already high before it is deaerated.

### Direct Acid Treatment

Acid treatment of boiler feedwater is the continuous addition of acid to the water to correct a condition of excess alkalinity or undesirably high pH. Acid treatment is becoming common. With proper acid feeding equipment such as modern proportional feed devices and pH control equipment, it is no longer a hazardous operation. Acid treatment of boiler feedwater is normally conducted for the prevention of zeolite disintegration by reducing the pH valve of high alkaline influent waters.

## WATER HARDNESS TESTS

Analyzing the water is the process of determining how much of various substances are present within the water. Complete analysis of watr is a job for an experienced chemist, but operators should learn to make routine tests for control of feedwater treatment. Two tests which are normally performed by the operator are for water hardness and brine concentration.

Calcium and magnesium slats cause hardness in water, scale in boilers and the inhibition of soap lather, as discussed before.

If hardness is responsible for so many bad conditions in water, we should determine just how hard the water is before it goes into the boiler. One of the methods used to determine hardness is called the "SOAP HARDNESS TEST". Soap is used in a sample of water to achieve a soap lather. The more soap needed for a lather, the harder the water.

Another method of testing water for hardness is the "VOLUMETRIC HARDNESS TEST", which is more accurate than the soap hardness test, but more elaborate test equipment is needed.

## PERFORMING EXTERNAL TREATMENT TESTING

Analyzing a water sample is the process of determining how much of various substances are present within the water. Complete analysis of water is a job for an experienced chemist, but operators should learn to make the routine tests that are necessary for the control of feedwater treatment. Such tests that are necessary especially in softening processes are tests for water hardness, the brine test and the deaerating test.

A standard soap solution is one of the items needed in order to perform tests for hard water and soft water. Many different soap solutions may be purchased; however, each one does not have the same lather factor. The lather factor must be known before the soap hardness test can be performed. The lather factor on most standard soap solutions will be clearly marked on the label. When the lather factor is not known, the following information can be used as a guide in determining the lather factor of a standard soap solution.

--- Prepare about one-half pint of pure distilled water, having less than .5 ppm of chloride.

--- Pour 30 ml of the distilled water into an 8-ounce bottle.

--- Using a .5 ml dropper, put one drop of standard soap solution into the bottle containing the distilled water. Stopper the bottle and shake vigorously, then lay the bottle on its side and observe the lather formed.

--- If the lather formed persists and completely covers the surface of the water for five minutes, one drop will be your lather factor for this particular solution. If not, continue adding drops until you find out how many drops in the lather factor. Once this information is known, record the amount of drops as the lather factor.

--- Once the lather factor is known, we are ready for the hardness test using the standard soap solution.

### Hardness Test, Using Soap Solution

--- Pour 30 ml of the sample to be tested into an 8-ounce bottle.

--- Using a .5 ml dropper, add drops of standard soap solution to the sample a drop at a time. After each drop, shake vigorously; repeat this step until a lather can be formed that will last five minutes while the bottle is lying on its side.

--- After a lather has formed that will last five minutes without breaking up, take the total drops used and deduct the amount of drops required by the lather factor. The remaining drops left will equal GPG (grains per gallon) hardness of the sample. To change GPG to ppm (parts per million), multiply GPG by 17.1.

EXAMPLE: The amount of soap solution usd 11 drops, lather factor 1 drop. Deduct 1 from 10, leaving 10 drops; 10 drops are equal to 10 GPG. To change GPG to ppm, multiply 10 by 17.1 which equals 171 ppm hardness.

--- Rinse and clean all test equipment.

**Measuring Total Hardness by Volumetric Titration with a Versenate EDTA (Disodium Ethylene Diamine Tetra Acetic Acid) Solution**

--- Measure 50 ml of water sample in a graduated cylinder and then pour into a casserole.

--- Add .5 ml of total hardness buffer solution and mix using the rubber-tipped end of the stirring rod.

--- Add one measure of hardness indicator powder; if powder is not available, use hardness indicator tablet and pulverize using the glass stirring rod.

--- Fill the burette to the zero mark with versenate hardness reagent which is done by squeezing the plastic bottle attached to the automatic burettes.

--- Slowly add the hardness reagent while mixing constantly. The end point is a blue color. Specifically, it is the blue color that is present when the last trace of reddish color has just faded.

--- Read the number of ml on the burette and determine the ppm of total as $CaCO_3$ by using the fomula 20 X ml of titrating solution, and record the answer.

--- Rinse and clean all equipment.

SUMMARY

The removal of iron, carbon dioxide and turbidity is best achieved by the chemical precipitation methods of Cold Process Lime-Soda Softening or Hot Process Lime-Soda Softening. Aeration is a method that is used primarily to remove carbon dioxide and hydrogen sulfide, which causes corrosion. Aeration results in saturating water with oxygen, a corrosive gas. Deaeration is a process that removes the gases of oxygen, carbon dioxide and ammonia from the water. Direct acid feed is sometimes required to help neutralize an excess of alkalinity.

QUESTIONS

1. What is meant by clarification of water?

2. How is coagulation achieved?

3. Why are coagulation and filtration sometimes used in conjunction?

4. Explain the ION exchange principle.

5. Name two types of chemical precipitation processes.

6. What is the purpose of a deaerator?

7. What is the purpose of an aerator?

8. How can the pH level of water be lowered?

9. Name two hardness tests.

10. What is lather factor?

11. What is the X-factor between grains per gallon and parts per million on the soap test?

REFERENCES

1. AFM 85-12, Volume I, Operation and Maintenance of Central Heating Plants and Distribution Systems.

2. AFM 85-31, Industrial Water Treatment.

# INTERNAL TREATMENT

## OBJECTIVES

Given information, identify principles related to internal boiler water treatment with 80% accuracy.

Given information, select, care and use precision measuring instruments with instructor assistance.

Following step-by-step procedures, draw water sample and determine chemical concentrations in a steam boiler with instructor assistance.

Given information, explain basic facts pertaining to condensate return treatment with 80% accuracy.

Given step-by-step procedures, test and treat condensate return water with instructor assistance.

## INTRODUCTION

Regardless of whether one is concerned with manpower or materials, well-laid plans will normally fall by the wayside if a means of controlling is not included in the program. This is particularly true of boiler feedwater treatment. The most important factor in boiler water treatment for prevention of scale and corrosion is proper control of the chemicals used in treatment. Unless all treatment chemicals are controlled within specified limits, the treatment is ineffective, steam contamination may result, and damage to the boiler will occur. Frequent testing at stated intervals is the only positive method for determining the concentration of chemicals in the boiler. By knowing the chemical concentration in the boiler, we are able to determine the amount of chemicals that will have to be added to maintain the specified limits.

Generally, the makeup water that comes into the boiler with the feedwater brings dissolved calcium and magnesium that can form scale. As a practical matter, these hardness elements cannot be kept in solution in the steaming boiler water. They will precipitate, and the main purpose of internal treatment is to control precipitation to form a sludge that can be run off with the blowdown instead of a scale that causes trouble. This control is what prevents scaling in boilers, and herein lies the use of all endless numbers of boiler "compounds", the mysteries, the arguments and much foolishness.

## INFORMATION

### OBJECTIVES OF INTERNAL TREATMENT

Internal treatment for scale prevention would serve no useful purpose if the sludge formed deposits in the boiler, expecially where the heat is coming through from the fire. Sludges often have to be "helped" so that they will be carried along with the water and leave the boiler with the blowdown. Additives that do this are called "sludge conditioners".

When precipitates form in the boiler water, the character of the sludge can vary depending on conditions in the boiler. Sometimes, the particles are fine and sometimes course. Some sludge floc will and some do not. The main thing is how the sludge flows, and it was discovered early that some additives cause the sludge to flow better. Most of these are organic substances having large molecules that dissolve in water to form a colloidal suspension. One of the earliest schemes was to put potato peelings into the boiler. This sometimes helped because starch is a useful colloid.

These colloids act something like a gelatin in the boiler water. The gelatinous particles bring the precipitated particles together to form a sludge but do not permit the small crystals to grow in size. Whatever the action, circumstances may cause it to vary, and its extent cannot always be predicted. This has given rise to searches for the very best additives of this kind. Vegetable products, known as tannins, are used a great deal and one of these, extracted from quebracho wood, is used in many government-operated boilers. A related class is the lignins that are left over when paper is made from wood. Starch is used on many Navy ships, where the large amount of chlorides in the water causes special problems. Another common colloid additive is extracted from seaweed.

What substances to use and how much are learned largely through experience, watching how the sludge behaves. For example, quebracho tannin has given very good results in heating plant boilers (pressures to 250 psi). However, charring and black deposits have been reported in some of the higher-pressure power plants and process-steam boilers in which this tannin was used. The reported deposits were probably formed because the feedwater treatment had not been well planned. The point is that quebracho tannin did not keep the poor-grade sludge fluid. In these same situations, certain lignin-class chemicals are often better sludge conditioners; but, these too can cause black deposits in high-pressure boilders.

### Formation of Scale and Deposits in Boilers

Minerals or salts present in the feedwater in dilute form become concentrated in the boiler water. The slightly soluble minerals can therefore deposit or precipitate out of the boiler. They may come out in the form of a scale on the boiler surface or in the form of a sludge throughout the body of the boiler water.

The slightly soluble materials include calcium sulfate, calcium carbonate, and magnesium hydroxide and, where phosphate treatment is used, calcium phosphate is precipitated and a magnesium phosphate deposit can be formed. Very soluble salts present in a boiler water which do not come out of solution include principally the sodium salts, such as sodium carbonate, sodium sulfate, sodium chloride and sodium nitrate, and also any potassium salts.

CALCIUM CARBONATE DEPOSITS. Calcium bicarbonates present in feedwater decomposes in the boiler to form calcium carbonate, usually mostly as a sludge. The concentration of calcium bicarbonate in a water may be quite high. In such instances calcium carbonate can deposit in the feedwater heater or in the boiler feed lines because of the temperature to which feedwater is ordinarily heated. Deposition of the calcium carbonate becomes more rapid at the temperature in the boiler. If the deposition occurs in a water low in causticity, as it has not yet mixed with the concentrated caustic boiler water. Considerable calcium carbonate deposit may therefore accumulate at the feedwater inlet. Under the influence of heat, this deposit can be baked on and become similar to a thick, hard scale. Ordinarily, the calcium carbonate sludge can be removed by blowdown. Sometimes it may not be sufficiently fluid to be carried well enough in the circulating boiler water, so that it settles and is baked to a thick, hard scale.

CALCIUM SULFATE SCALE. This salt is somewhat soluble in cold water, but its solubility decreases as the temperature of the water increases. It can therefore deposit directly on the boiler surface where the boiler water is hottest and form a hard scale, which builds up in thickness.

MAGNESIUM DEPOSITS. Magnesium bicarbonate present in a water decomposes under the influence of heat, to form magnesium carbonate. These magnesium deposits can form, to some extent, in boiler feed lines or at the boiler feed inlet in the same way as calcium carbonate to form a hard scale. In the boiler, magnesium hydroxide may form as a sticky sludge and adhere to boiler surfaces. Under some conditions, however, magnesium deposits can form in hard scales or baked-on sludges.

## FACTORS CONTROLLING BOILER WATER TREATMENT

Many factors, in addition to proper chemical feed, affect the control of treatment-chemical concentrations in boiler water. These factors are operational as well as mechanical.

### Variation in Condensate Losses

Extreme variation in the amount of concensate returned, caused by improper pump operation and maintenance, lowers the concentrations of treatment chemicals in boiler water. This is due to high makeup rate when appreciable condensate losses occur. The high makeup rate imposes an excessive demand for chemical treatment above that normally fed when all return pumps are operating properly. To remedy this, check the area from which the condensate is returned and see that pumps are operating properly. High makeup rates complicate the problem of chemical treatment control.

### Blowdown

Excessive or incorrectly times boiler blowdown also lowers the concentrations of treatment chemicals in a boiler. Give blowdowns only when chemical tests show they are needed; emphasize particularly the results of the dissolved-solids test. Blowdowns must be given before treatment chemical is added, unless supplementary batch or automatic intermittent feed over a 24-hour period will maintain adequate concentrations of treatment chemicals in the boilers throughout the blowdown. Do not fill the boiler with water just before the blowdown.

### Scaled Boilers

Scale is a crystalline deposit formed on the evaporating surfaces of the boiler. The most common scales in heating boilers are calcium carbonate and calcium sulfate. These deposits, if allowed to become thick enough, will cause the boiler metal to overheat and fail. The presence of scale is evidence of ineffective water treatment. These scales can be removed by chemical solvents. However, this is a specialized and a hazardous process. The guidance of an engineer experienced in chemical cleaning is advisable to determine if a special water treatment or chemical cleaning will remove the scale.

## REQUIREMENTS FOR TREATMENT

### Boiler Classifications

The basic requirements for treating boiler water vary with water quality and boiler construction, materials, operating pressure, capacity and design. Steam boilers are generally classified as high-pressure, high horsepower; high-pressure, low horsepower; low-pressure, high horsepower; and low-pressure, low horsepower. Steam boilers made of steel may operate at either high or low pressure. Cast iron boilers operate at low pressure. High-pressure boilers operate at pressures in excess of 15 psi steam, while low-pressure boilers are those that operate at a pressure of 15 psi or less. High horsepower boiler plants are equipped with individual boilers rated at 100 hp (horsepower) or more. A boiler plant equipped with one boiler rated at 100 hp or more plus one or more boilers rated at less than 100 hp is classified as a high horsepower plant. High horsepower boiler plants may operate at high or low pressure. Low horsepower plants are equipped with individual boilers rated at less than 100 hp. These plants are also operated at either high or low pressure.

### Methods of Treatment

Chemical treatment requirements, method of control and application vary with the makeup water and the boiler. The following paragraphs can serve as a guide for internal boiler-water treatment requirements.

HIGH-PRESSURE STEAM STEEL BOILERS. These boilers are generally treated with caustic soda in combination with sodium metaphosphate and quebracho tannin. Boilers under 10 hp are exempt from this treatment unless local conditions warrant it.

LOW-PRESSURE STEAM STEEL BOILERS. These boilers are generally operated without makeup or blowdown, and are therefore usually free from corrosion and scaling troubles. If makeup is required for some reason such as process requirements, corrosion and scale sometimes become problems. When they do, the boiler may be treated with caustic soda or with caustic soda and quebracho tannin. If the boiler is operated with acidic or low-alkalinity water, without makeup or blowdown, give it a sufficiently large dose of caustic soda to impart alkalinity in the rage neeced to prevent corrosion -- pH 10.5 to 11.5. If scale formation is observed, treat the boiler with caustic soda in combination with sodium metaphosphate and quebracho tannin.

CAUTION: If in doubt, consult the major command.

LOW-PRESSURE CAST IRON BOILERS. Boilers of this type are not treated unless scale formation is observed. Where treatment is necessary, use caustic soda in combination with sodium metaphosphate and quebracho tannin.

CAUTION: When such treatment is indicated, consult the major command before instituting it.

**SPECIAL TREATMENT.** In some cases, both low- and high-pressure boilers may require special water treatments, such as sulfite or antifoam.

CAUTION: Consult the major command before instituting treatment.

## TYPES OF INTERNAL BOILER WATER CHEMICALS

To prevent scale formation on the internal water-contacted surfaces of a boiler and to prevent destruction of the boiler metal by corrosion, feedwater and boiler water must be chemically treated. This chemical treatment prolongs the useful life of the boiler and results in appreciable savings in fuel since maximum heat transfer is possible from the furnace to steam.

The chemicals mentioned in this text for use in AF boilers are not always used in every boiler. The chemicals used in a particular boiler in one area may not be needed for a boiler in another area. The condition of raw water and intended use of the boiler and steam are factors considered before deciding what chemical treatment (if any) will be used.

The chemicals used in treatment of AF boilers are as follows.

### Caustic Soda (NaOH)

Addition of caustic soda, so as to maintain a concentration of 20-200 parts per million (ppm), will neutralize acid conditions and provide sufficient free hydroxides to combine with the magnesium salts in the boiler and will not adhere to the heating surfaces. Addition of caustic soda also enhances the achievement of other boiler water objectives. It keeps the boiler sludge fluid so that it is carried in the circulating water and can be removed by blowdown; it helps maintain smooth effectiveness of certain chemicals such as phosphate, quebracho tannin; and, it is required by some neutralizing amines for good volatility with the steam.

### Tannin

Tannin decreases sludge accumulation and scale formation in the boiler. For this reason, it is frequently used as a supplement to caustic soda treatment to enhance removal of calcium phosphate sludge. Quebracho tannin has a corrosive control property in that it absorbs some of the dissolved oxygen and more important, appears to form a protective film on steel. It should be used when detailed precautions for full protective corrosive controls are not practical or economical. Tannin also provides smoother boiling with less carryover and, although Air Force boiler plants rarely present embrittlement problems, gives added assurance that such problems will not develop. The limit for tannin content of boiler water is a medium brown color (3M) as shown by the middle standard of the tannin color comparator.

Excessive amounts of tannin cause foaming and in addition becomes sticky and adheres to boiler surfaces making it difficult to remove by blowdown, plus the settling of sludge may restrict water circulation resulting in starvation of water-wall tubes. Over-treatment of tannin also results in loss of chemicals, heat and water because of excessive blowdown.

### Phosphates ($PO_4$)

A concentration of 30-60 ppm of phosphate should be maintained in the boiler water. When boiler water is treated with a phosphate chemical, the phosphate combines with the calcium to precipitate calcium phosphate. Calcium phosphate forms as a finely divided fluid sludge which can be carried by the boiler circulation and readily removed by blowdown. Since calcium phosphate is the least soluble of the calcium salts that form in a boiler water, phosphate control prevents the formation of calcium scales, such as calcium carbonate or calcium sulfate. Maintenance of a satisfactory causticity in the boiler water is necessary with phosphate control because calcium phosphate is more soluble if the water does not carry enough causticity and can form as a sticky sludge that will adhere to the boiler surfaces.

Excessive concentrations of sodium phosphates not only indicate wastage of chemicals, but can also increase formation of sticky sludge and scale. If too high of a concentration of phosphate is maintained, the phosphate will start precipitating magnesium. Magnesium phosphate is very sticky and will adhere to boiler surfaces causing scale formation thus defeating the purpose of internal treatment. To prevent this, maintain a 3 to 1 ratio of sodium hydroxide to phosphate. This way the sodium hydroxide will precipitate the magnesium and leave the precipitation of calcium to phosphate.

Sodium Sulfite ($2Na_2SO_3$)

In certain instances, some corrosion may persist even though sufficient causticity is carried and the feedwater deaerated. Sometimes, improved corrosion control is obtained by chemical treatment to remove the small quantities of oxygen left in the water after it has been deaerated mechanically. A few chemicals are available for this purpose; the most commonly used is sodium sulfite. When dissolved in water, it unites with oxygen to form sodium sulfate. If enough sodium sulfite is fed into a boiler, the chemical surplus maintained in the water will take up any oxygen that enters and keep the boiler oxygen free. Normally, a concentration of 20-40 ppm sodium sulfite is maintained in the boiler water. This is enough to take up any oxygen that is likely to get into the boiler. Higher concentrations are unnecessary and wasteful.

Table 2 on the following page gives the concentration level for the chemicals you studied in the preceding paragraphs.

## OBJECTIVE OF AMINE TREATMENT

### Methods of Minimizing Return-Line Corrosion

Corrosion in condensate return lines and associated equipment is a problem common at many Air Force bases. The causticity in the boiler water is not volatile and ordinarily only small amounts, if any, goes over with the steam; therefore, the condensate is generally rather pure water. However, carbon dioxide ($CO_2$) gas does go over with the steam and dissolves in the condensate, causing carbonic acid, lowering the pH or the return condensate and making it acid. The carbon dioxide is more corrosive than the oxygen which leaks in at pipe connections, pumps, etc. But when both are present, the problem is intensified and a corrosion problem is likely to exist. Acid corrosion usually grooves and channels the bottom of the pipe; frequently, it is most pronounced just beyond the traps of hot water generators or radiators. Oxygen normally pits the entire circumference of the pipe. Return line corrosion can be controlled with neutralizing and filming amines.

NEUTRALIZING AMINES. Most condensate corrosion problems are caused by carbonic acid in the condensate. The carbonic acid is derived from mineral carbonate in feedwater makeup. Therefore, caustic soda rather than soda ash, which is also a carbonic acid source, is used for internal boiler water treatment. To neutralize the condensate carbonic acid, treat the boiler water with an alkaline material that carries over with steam. A group of volatile, alkaline compounds called "amines" satisfies this requirement. When fed into the boiler water, the amines volatilize to form a gas which flows over with the steam and returns with the condensate to the boiler where it is reused. Loss of condensate results in loss of chemical. The alkalinity of the amine builds up the condensate pH and, on the alkaline side (about 7.0 to 7.5). The neutralizing amines approved for Air Force use are cyclohexylamine and morpholine.

--- Cyclohexylamine. Two grades of cyclohexylamine are available: water solution which is 60 percent cyclohexylamine, and a special grade which is 98 percent cyclohexylamine. The 98-percent grade is more economical; however, since it is about as flammable as alcohol, it must be diluted with an equal volume of water when received at the plant. Cyclohexylamines are sold under various trade names and may vary somewhat in concentration percentages.

Cyclohexylamine is caustic and harmful to the skin. Handle it carefully to prevent spilling it on the skin or breathing the fumes excessively.

When used in direct contact cookers, cyclohexylamine may be used if it does not exceed 10 ppm in the steam. DO NOT use such steam where it will contact milk products.

| CHEMICAL | RESIDUAL (CONCENTRATION) | PURPOSE | * X-FACTOR |
|---|---|---|---|
| SODIUM SULFITE | 20-40 P. P. M. | OXYGEN SCAVENGER | -1 Drop x 5 = P. P. M. |
| CAUSTIC SODA (SODIUM HYDROXIDE) | 20-200 P. P. M. | ALKALINITY (Also precipitates magnesium) | 23 x ML = P. P. M. |
| PHOSPHATE | 30-60 P. P. M. | PRECIPITATES CALCIUM AND MAGNESIUM | Color Comparison |
| TANNIN | $3^{\underline{M}}$ | KEEPS BOILER SLUDGE AND SOLIDS IN LIQUID OR FLUID STATE | Color Comparison |
| DISSOLVED SOLIDS TEST (D. S.) | 1000-4000 P. P. M. | DETERMINES AMOUNT AND FREQUENCY OF BLOWDOWN | Tannin Conversion Factor |
| AMINES<br>CONDENSATE pH | 7.0-7.5 pH | PREVENTS CORROSION IN CONDENSATE RETURN LINES | |

*X-FACTOR -- is the multiplication factor used to convert the chemical analysis into parts-per-million.

T[illegible]e 2. Concentration Levels

--- Morpholine. Morpholine is a neutralizing amine sold in a 91-percent solution. It is less volatile than cyclohexylamine; consequently, it is used in plants which operate at high pressures and ratings, usually above 50 psi. In situations in which its use is applicable, it has one distinct advantage. It releases $CO_2$ more readily than cyclohexylamine does and, in a properly vented system with a good deaerating heater, has a higher recycling capacity.

The same precautions and procedures set forth for cyclohexylamine apply also to morpholine.

FILMING AMINES (OCTADECYLAMINE). The filming amines do not neutralize carbon dioxide. Rather, they function by forming an impervious nonwettabe film on the metal surface. This film serves as a barrier between the metal and the condensate, thus protecting against both oxygen and carbon dioxide attack. This amine film causes the water to assume droplet form which, in addition to providing protection, results in a subsidiary benefit -- that of increased heat transfer efficiency. Reports of increases of 5-10 percent in heat transfer efficiency are not uncommon. Unlike the neutralizing amines, which must be fed in direct proportion to the $CO_2$ content, the filming amines are generally dispersed so as to provide a feeding rate of 2-3 ppm. Except at a very low $CO_2$ concentration, treatment of filming amines, as opposed to neutralizing amines, is considerably more economical.

### Choice of Amine Treatment

Use condensate corrosion testers to determine if treatment is needed. Testers may be obtained from the US Air Force Contract Laboratory. When condensate corrosion testers indicate treatment is required, the choice of amine must be based on oerating conditions. The following is a general guide. When boiler feedwater makeup is 20 percent or less, the neutralizing amines are normally used; treat boilers that operate to about 50 psi with cyclohexylamine; use morpholine for those which operate at higher pressures or at a high sustained load. The filming or octadecylamine may be used if makeup requirements are fairly high or oxygen is suspected as a major cause of return-line corrosion.

## DRAW BOILER WATER SAMPLE

### Sampling Connections

If we use a chemical in our boiler, we must be able to tell at all times when we have enough of that chemical in the boiler. To do this, we must have a sample of the water that is in the boiler. We could get water out of the boiler from many different fittings, but the water should represent all the water in that boiler. Therefore, we would not get our sample from the bottom blowdown because it would contain too much sludge. On the other hand, we should not get our sample from the steam space because chemicals are not present in steam.

### Importance of Accuracy

For adequate treatment control, the boiler water being tested must represent the true condition of the water in the boiler when it is operating. Exercise care in selecting the sampling point and the drawing-out method. The sample connections should all be tight fitting and installed to permit the sample to be taken while standing on the floor, for obvious safety reasons.

If water-column connections to the boiler are short and direct, blowdown the water column several times and draw a sample from the water-column blowdown connection. Install a 1/4-inch sampling conectin ahead of the water column blowdown valve. For water-tube boilers, take the sample from either the front drum or the forward part of the upper rear drum. Continuous blowdown connections properly located make good sampling points. If the rear drum connection is close to the feedwater inlet, be sure that the sample is not diluted by feedwater. If any doubt exists as to the proper location of the sampling connection, contact the major command for assistance.

### Types of Cooling Coils

If possible, draw the boiler water samples through a cooling coil that prevents the boiler water from flashing into steam. Several types of commercial cooling coils are available. Coils are also easy to make in the plant.

**ATMOSPHERICALLY-COOLED COIL.** About 25 feet of 3/8- or 1/2-inch copper tubing bent in the shape of a large helix and suspended in air makes a satisfactory air condenser if the sample is not drawn too rapidly.

WATER-COOLED COIL. Good results can be obtained with 15 to 25 feet of 1/4-inch copper tubing formed into a coil approximately 6 inches in diameter and 10-inches long and immersed in a bucket of cold water or a permanently connected cooling chamber. A common manifold permits the coil to serve two or more boilers.

We have no set time to draw a boiler water sample, but all samples must be drawn immediately before the regular blowdown and before chemicals are added. Unless otherwise specified, bring samples for all water analysis tests described below to room temperature. This is necessary to determine minimum concentrations of the chemicals available in the boiler and the maximum total-dissolved-solids content of the boiler water. All testing apparatus must be scrupulously clean and kept and used in clean surroundings protected from dust and dirt.

Before collecting the sample, blowdown all sampling lines and connections to sampling points to clear them of stagnant water. If possible, avoid taking flash samples by drawing the sample slow enough to cool the water before it comes out the end of the sample line (see figure 13).

Adjust the sampling line to reach to the bottom of the bottle; then run the sample long enough to overflow the top to protect it from exposure to the atmosphere (see figure 13.) This is necessary because the carbon dioxide and oxygen in the air can be absorbed and change the causticity and tannin concentrations of the sample. Never take the sample in a shallow pan or bucket and do not expose it to the air any more than is necessary.

Extreme care must be taken when drawing a boiler water sample because a mistake at this time can affect the results of the boiler water tests. If the boiler water tests are wrong, the sater treatment logs will be wrong; the wrong amount of chemicals will have been placed in the boiler; and, you may give the boiler too much blowdown, thus wasting more chemicals, water (hot water) heat, time and energy. A slight mistake at the begining affects the end.

Generally speaking, water samples taken in a steam heating plant include water taken from the boiler and the return line. In hot water heating plants, one water sample is usually all that is required. This sample is obtained either from some convenient point in the system or from the boiler drain valve or cock.

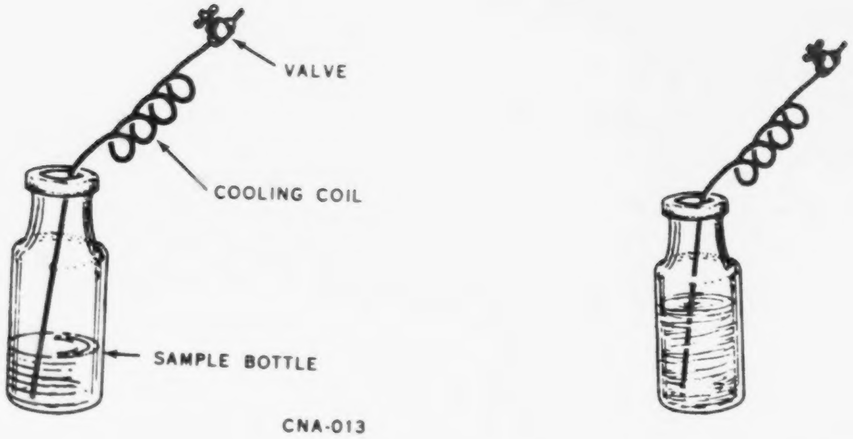
## Standard Laboratory Equipment

An arrangement with the US Air Force Contract Laboratory permits Air Force activities to obtain the necessary test kits and reagents by direct request to US Air Force Contract Laboratory. Kits are available to test for causticity, phosphate, tannin, pH of boiler water (low-pressure boilers), pH of return condensate and sodium sulfite.

For blowdown control, the dissolved solids of boiler water may be determined rapidly and simply by use of a modified Wheatstone bridge to measure the specific conductance of a water sample and converting its value to parts per million. The instrument and conductivity cell is listed in Equipment Allowance Document TA404 under stock number 6630-678-5582 Test Bridge, Solution Conductivity. The additional equipment required for this test is available on request from the US Air Force Contract Laboratory.

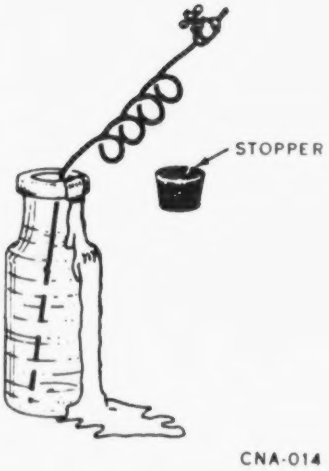
## Laboratory Furniture

Adequate space and equipment should be made available in the heating plant to facilitate testing. Equipment should include the following basic items of furniture: sink, preferably with an intergral drain board; shelf; cabinet, a unit for the distillation or demineralization of water (if demineralized water is not available from other base sources). Items for cleaning and maintaining laboratory equipment should also be available.


VALVE
COOLING COIL
SAMPLE BOTTLE
CNA-013

a. Blowdown sample lines
b. Rinse equipment
e. Discard rinse water

d. Draw sample slowly
e. Sample line to bottom


STOPPER
CNA-014

f. Overflow bottle
g. Stopper bottle
h. Label bottle

Figure 13. Taking a Boiler Water Sample

## Technical Assistance

The appropriate major air command provides technical assistance to train personnel in control of chemical treatment, testing procedures and related problems, such as return-line corrosion, feedwater heater operation, and those concerning treatment or conditioning of steam, condensate and boiler feedwater.

## Information for Ordering Supplies and Equipment

Ordering supplies is not difficult if the following rules are observed.

---- Stocklisted items must be ordered when they will fill the requirements.

---- Always describe items as completely and accurately as possible. (Supply people do not know your requirements.)

---- Doublecheck substitutions or similar items and be sure they will meet your requirements before ordering them.

When ordering boiler water supplies, submit proper forms. It is advisable to make an extra copy for the laboratory file so that a record of delivery, amount ordered and consumption may be kept.

When ordering an item or reagent that is stocklisted and the stock number is known, all that is necessary is to check the stock catalog and copy the nomenclature and description accurately and completely.

## Laboratory Safety

The work of a laboratory specialist in water treatment can be safe if he will use a few simple precautions in the handling and mixing of chemicals, handling glassware and operating the equipment. Accidents just do not happen; they are caused by unsafe acts or conditions. The skilled operator knows his chemicals, the proper method of mixing them, the correct manner of operating his equipment, and the importance of keeping his mind on his work. The last is very important because many times after an accident, the victim has remarked, "I was not thinking". Information of importance to you in gaining an understanding of how accidents are caused and prevented is presented in this study guide. However, not all the information you need to know is contained here; therefore, additional study on the subject is recommended.

## Handling Acids and Alkalies

Acids and alkalies can cause severe burns when they come in contact with the skin. When handlig chemicals, never put your hands to your eyes or face without first washing them. The skin tissue of your face is more sensitive than that of your hands and is more easily irritated. Rubber gloves must be worn when handling concentrated acids to protect your hands. To protect your clothes a rubber apron is worn, Before using these protective devices, they should be inspected to assure they will afford the protection for which they were intended.

When mixing acids with water, the acid should be slowly poured into the water and the solution should be constantly stirred with a glass stirring rod to prevent a concentration of the acid in a small area of the water. Failure to follow this procedure may result in the acid boiling and splattering the surrounding area, causing severe burns to the operators. Never pour water into the acid. Should one of your co-workers get a spray of acid in his face or eyes, do not let him put his hand to his face, place him immediately under a shower where plenty of water can wash away the acid, and then take him immediately to the doctor for further treatment. An accident report should be made as soon as the patient's condition permits.

## Cuts from Glassware

Before using any glassware for testing water, an inspection of the article should be made for cracks and rough edges. The rough edges can develop into cracks and when a stopper is applied may break the tube and spill its contents.

When heating a liquid in a breaker or flask, always apply the heat gradually. A large amount of heat concentrated in a small area can set up a strain that might cause the beaker or flask to crack.

## Laboratory Safety Equipment

Although some differences will be found in safety equipment which has been provided for use in the water testing laboratories, most laboratories will have similar items of safety equipment.

Rubber aprons are provided and should always be worn when you are performing water tests. This practice will protect your clothes from water spills and also from acid and other chemical spills.

Rubber gloves are available and are a "must" when you handle concentrated acids such as sulfuric or nitric acid; also, when handling concentrated caustic solutions such as sodium hydroxide. Most of the acid solutions used in testing water samples are quite weak (N/50) and do not require the use of rubber gloves.

Asbestos gloves are provided for the handling of beakers and other vessels containing hot liquids and also when removing hot samples from a muffle furnace.

Several types of tongs may be provided for handling equipment which cannot be picked up with your bare hands. Some of the tongs have rubber covered tips so that glassware may be handled without danger of cracking. Other tongs are asbestos lined for handling the larger beakers containing hot liquids.

Plastic face shields and eye goggles are provided for your protection when handling concentrated acid or caustic solutions and when heating solutions and evaporating them to dryness over Bunsen burners as there is some danger of splatter just before dryness is reached.

Some laboratories are equipped with emergency showers and also special eye washers. Although this equipment may never be needed, you should give them an operational check at regular intervals, and you should make sure that you know exactly where they are located.

Properly equipped laboratories will be well ventilated and some are provided with exhaust fans for the quick removal of toxic or noxious fumes.

Walkways in the laboratory may be covered with rubber floor mats to lessen the chance of slipping and falling. They also act as an electrical insulator and decrease the possibility of receiving an electrical shock when operating electrical powered stirring machines, etc.

## Testing Equipment

Testing equipment must be kept in good repair and be scrupulously clean when used, otherwise, test results may be erroneous.

Clean testing apparatus thoroughly with soap and water using the test tube brush provided. Distilled water or condensed steam makes a good rinse. The equipment should be kept and used in clean surroundings protected from dust and dirt.

The electrical conductivity meter cell, used in the dissolved solids test, should be inspected at intervals. Check for the following: is wear and cracking noted; is there foreign material on the electrodes; is shield in position, intact; and are the electrodes in position; are vent holes free of obstruction; is the black platinum coating present over all the electrode surfaces?

NOTE: If mechanical defect is noted in the cell or if loss of the black platium coating on the electrodes is noticed, the cell can be returned to the manufacturer for repair or replatinizing of the electrodes.

When not in use, the cell should be stored submerged in distilled water.

A cell frequently used should be cleaned every few weeks. This may be done by dipping the cell in 3N hydrochloric acid for about two minutes, followed by washing in running water and inverting the cell to wash the electrodes.

Calibration of the meter should be done once each month. This can be done by measuring the specific conductance of the calibration solution (Conductivity Meter Test Solution available from the AF Contract Laboratory). Use the same procedures as the boiler water test for dissolved solids, including setting the temperature adjustment to the temperature of the solution. Neutralizing solution is NOT used. If the reading is appreciably outside the range, the cell can be adjusted locally or returned to the manufacturer for calibration.

### Chemical Reagents

PREPARATION OF STARCH INDICATOR. In testing boiler water for Sodium Sulfite content, a starch indicator is used. This indicator must be prepared locally. One-fourth level teaspoon of potato or arrowroot starch (available from AF Contract Laboratory) is mixed with 50 milliliters of distilled water. The starch solution loses its sensitivity as an indicator after a time. Addition of one crystal of Thymol (available from the AF Contract Laboratory) to the starch preserves it so that it can be used for about two weeks. The starch solution should be dated when prepared.

PREPARATION OF DILUTE STANNOUS CHLORIDE. In performing the Phosphate test, a solution of dilute stannous chloride is used. This reagent must be prepared from Concentrated Stannous Chloride on the day it is to be used. One-half milliliter of concentrated stannous chloride is transferred to a 20-milliliter bottle and the bottle filled to the neck with distilled water. After the test, discard any dilute stannous chloride reagent not used. Dilute Stannous Chloride that is not fresh gives low results in the Phosphate test. The dilute ragent cannot be supplied from a central laboratory as it deteriorates too rapidly.

The Concentrated Stannous Chloride deteriorates once the bottle is opened and should not be used if it is more than two months old. However, concentrated stannous chloride in the original sealed bottle can be kept for a period of six months without deterioration.

TESTING REAGENTS. The Comparator Molybdate and Concentrated Stannous Chloride reagents used in the Phosphate test should be tested at least twice a week, to insure that they are giving a correct blue color development in the test. This is done by testing for phosphate concentration in the Standard Phosphate Test Solution (available from AF Control Laboratory). The color obtained should be about midway between the two color standards of the Phosphate Comparator Block. If the color matches either standard or is outside the range of standards, the reagents must be replaced.

## BOILER WATER TEST

### Sodium Sulfite Test

The sodium sulfite test is performed to measure sodium sulfite content in the boiler water when this type of treatment is used. Sodium sulfite acts with oxygen very rapidly in the hot boiler water forming sodium sulfite. Sodium sulfite treatment is used to supplement mechanical methods and tannin as removal agents. When the remaining dissolved oxygen content remains high and sodium sulfite treatment is instituted, a concentration between 20 and 40 ppm is usually considered satisfactory.

### Causticity Test

The causticity test is used to determine the amount of free causticity or hydroxide (OH) in the boiler water. A causticity concentration maintained between 20 and 200 ppm, by using caustic soda, will neutralize acid materials in the water. In addition to the neutralizing action, the free hydroxide combines with magnesium salts to form magnesium hydroxide. Alkaline water will usually prevent corrosion. Our discussion will be limited to the precipitation method of testing. When testing boiler water which is appreciably colored by organic material such as tannin, it is desirable to start with a warm sample, say about 160°,

### Phosphate Test

The phosphate test is used to determine the amount of soluble phosphate in the boiler water. Maintaining a phosphate level between 30 ppm and 60 ppm by addition of sodium metaphosphate will result in the sodium metaphosphate combining with some of the free hydroxide (formed by the addition of caustic soda) forming Trisodium phosphate. The Trisodium phosphate combines with calcium salts, in the water, to form tricalcium phosphate, a soft, nonadhering, finely divided sludge which can be easily removed from the boiler by blowdown. There are several methods of determining the phosphate level; however, for our studies we will limit the discussion to the colormetric method.

### Tannin Test

The tannin test is made to determine the approximate concentration of tannin in the boiler water. Tannin acts as an oxygen absorber and due to its colloidal action, it can make the sludge form as very finely divided particles, thus being more fluid, so that it is carried by the circulating boiler water and is removed more readily by blowdown. The limit for tannin content of boiler water is a (3) medium brown color as shown by the middle standard of the tannin color comparator.

### Total Dissolved Solids Test

The dissolved-solids test is used to determine the concentration of soluble salts in boiler water and as a control to determine the amount and frequency of blowdown. The specific limits for boiler-water dissolved-solid content are between 1000 and 4000 ppm. Testing for dissolved-solids will be limited to the electrical conductivity method in this course.

### Condensate pH Test

Condensate return is tested for pH to determine if condensate alkalinity has decreased to the point where return-line corrosion will occur. This type of corrosion is common in installations having extensive return systems. When steam is formed, the bicarbonates in the feedwater go to carbonates in the hot water and form hydroxides. Carbon dioxide is formed in both actions and leaves with the boiler steam. When the carbon dioxide condenses with the steam, it forms carbonic acid giving a pH sometimes as low as about 5. By the use of a group of the compounds called "amines", the pH of the condensate can be maintained just on the alkaline side, say 7 .0 to 7.5, and corrosion in the return lines can be reduced.

TAKING THE SAMPLE OF CONDENSATE. Take the sample near a point in the return piping where the condensation takes place, such as right after a trap, or preferably at a point where return-line corrosion is known to be occurring. For the sample to be representative of water flowing in the return lines, it should not be taken from a collecting tank. Cooling the condensate is not necessary. However, collect it slowly to reduce flashing.

### Corrosion Testers

The literature on the corrosion of steel pipe recognizes two principal types that cause rapid perforation and failure: channeling, attributed to acidity; and pitting, ascribed to dissolved oxygen. Considerable damage may also be caused by erosion or mechanical wear, due to poor design of the system in relation to its loading. Testing devices such as wire coils, spools, and strips do not ordinarily distinguish between these causes of failure, especially in condensate. It is therefore difficult, with such tools alone, to determine whether the principal factor causing the deterioration was carbonic acid, dissolved oxygen, or an excessive rate of flow. This information was obtainable from the corrosion pattern in a test nipple.

The AF Contract Lab condensate-corrosion tester (figure 14) was developed to determine the need for chemical treatment to control corrosion in a particular heating system. The tester furnishes both weight-loss data and a corrosion pattern, from which the technologist can calculate the severity of corrosion and also determine the principal cause. The tester is essentially a nipple, whose inner surface is detachable so that it may be weighed and examined.

This tester is available at the AF Contract Lab. It determines whether chemical treatment to control corrosion of condensate-return liens is advisable and the effectivenes of any chemical treatment given. At the end of the test period, the tester is removed from the return line and returned to the AF Contract Lab for examination and evaluation. The tester is a composite test nipple, comprising a set of six rings or shells which fit inside a specially machined pipe nipple (see figure 14).

The average weight loss of the rings during exposure of the tester in a return-line system is evalutaed in terms of an average corrosion rate. The corrosion pattern shown on the surface of the cleaned rings indicates the responsible factor. The tester, a 3/4-inch pipe, is installed after traps that drain hot-water generators or unit heaters of equivalent capacity. The best way to install the tester is to remove the caps and insert it in a horizontal stretch of piping immediately beyond the trap. Usually, testers are placed at pooints where corrosion has been noticed. Ninety-day tests are recommended in plants with a history of corrosion trouble. Plants that have not reported high maintenance costs, frequently extend the test period over the entire heating season. Sixty to ninety-day tests are adquate to evaluate effectiveness of chemical treatments.

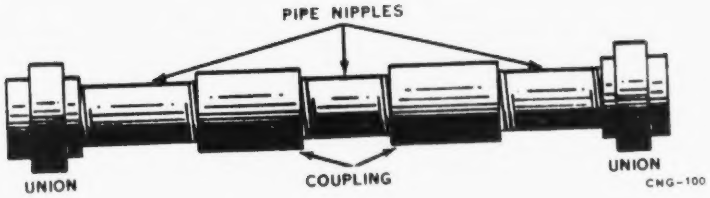


Figure 14. AF Contract Lab Condensate-Corrosion Tester Assembly

SUMMARY

A boiler water sample must be taken from a point that represents the overall boiler water. Analysis of the sample will determine the concentration levels of each chemical used. The condensate return water is tested for the pH level. Anytime chemicals are stored or handled all safety precautions must be followed precisely. One effective method for feeding chemical into the boiler water is the slug method. To determine the proper dosage of each chemical to add, the results of the water sample used must be accurate.

Water samples should be collected in a way that they represent exactly what they are supposed to represent. They should not be diluted, concentrated nor contaminated before testing and mailing. Samples are labeled to prevent getting them mixed up and to insure that they are sent to the correct place.

Boiler water samples for the AF Contract Lab should be carefully collected and labeled. (This sample should represent the same water that the operator samples on that day.) Forms should be filled out accurately and shipped the same day.

Sludge often has to be conditioned before it can be carried out along with boiler blowdown. This is accomplished by chemical treatment, which controls precipitation and the formation of suspended sludge. These chemical agents must be held within certain safe limits or they will become harmful. These limits must also be remembered when treating return-line corrosion.

Standard corrosion testers may be installed in the condensate lines which will indicate the rate of corrosion.

QUESTIONS

1. What is the main purpose for testing boiler water?

2. How does internal treatment prevent scale?

3. What is the purpose of treating boiler feedwater?

4. What standard chemicals are used to treat boiler feedwater?

5. What is the purpose of installing test nipples?

6. What does a causticity test determine?

7. What does a phosphate test determine?

8. What does a tannin test determine?

REFERENCES

1. AFM 85-12, Volume I, Operation and Maintenance of Central Heating Plants and Distributin Systems.

2. AFM 85-31, Industrial Water Treatment

# LOGS AND CHEMICAL FEEDING

## OBJECTIVES

Following step-by-step procedures, maintain water treatment log with 80% accuracy.

Given information and equipment, prepare boiler water sample for shipment with instructor assistance.

Given information and chemical formulas, compute chemical requirements with instructor assistance.

Given information, determine step-by-step procedures for installation and servicing of chemical feeding equipment with 80% accuracy.

Using step-by-step procedures, service chemical storage area with instructor assistance.

Using step-by-step procedures, perform chemical feeding with instructor assistance.

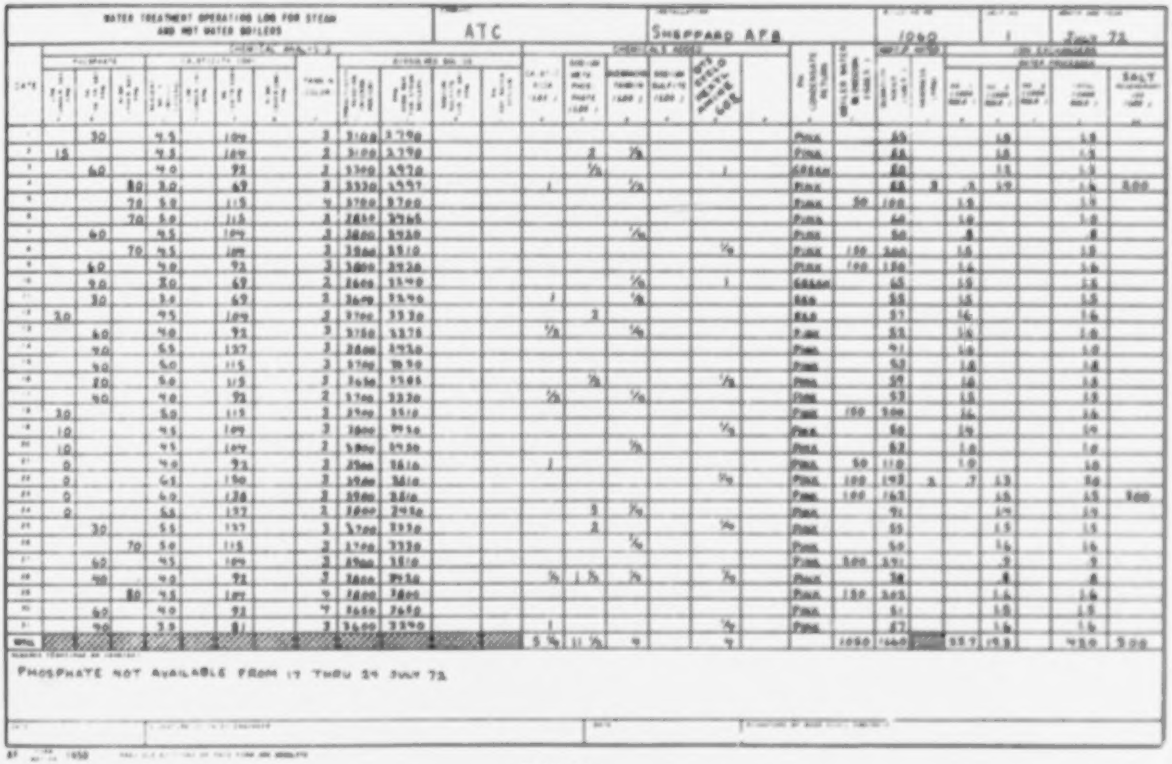
## INFORMATION

### PURPOSE OF LOGS

After you have tested your boiler water and determined the amount of each chemical in the sample, it is only fitting we should record this information. The purpose of AF Form 1459, Water Treatment Operating Log for Steam and Hot Water Boilers, is to provide a record of water treatment to boilers of all Air Force installations. These logs are active as long as the base or installation is active. The water treatment logs for a plant are maintained at a central boiler operation area. This report permits technical review of current performance and comparison of performance over a long period. Accumulated reports show variations due to changes in seasons and methods of operation.

The instructions for completing AF Form 1459 are found on the reverse side of the log. AF Form 1459 is used by all installations having steam and hot water boilers operating at pressures in excess of 15 pounds per square inch (psi) and HTHW in excess of 160 psi.

Figure 15 is an example of a completed log. The far left-hand column of the log is numbered from 1 through 31 under the "Date" heading. The date you draw your sample from the boiler is the same day you should test the sample. Record the results on the log and add chemicals or blowdown the boiler as needed. Instructions for filling out the log are printed on the reverse side (see figure 16).



WATER TREATMENT OPERATION LOG FOR STEAM AND HOT WATER BOILERS

ATC

Sheppard AFB

1060

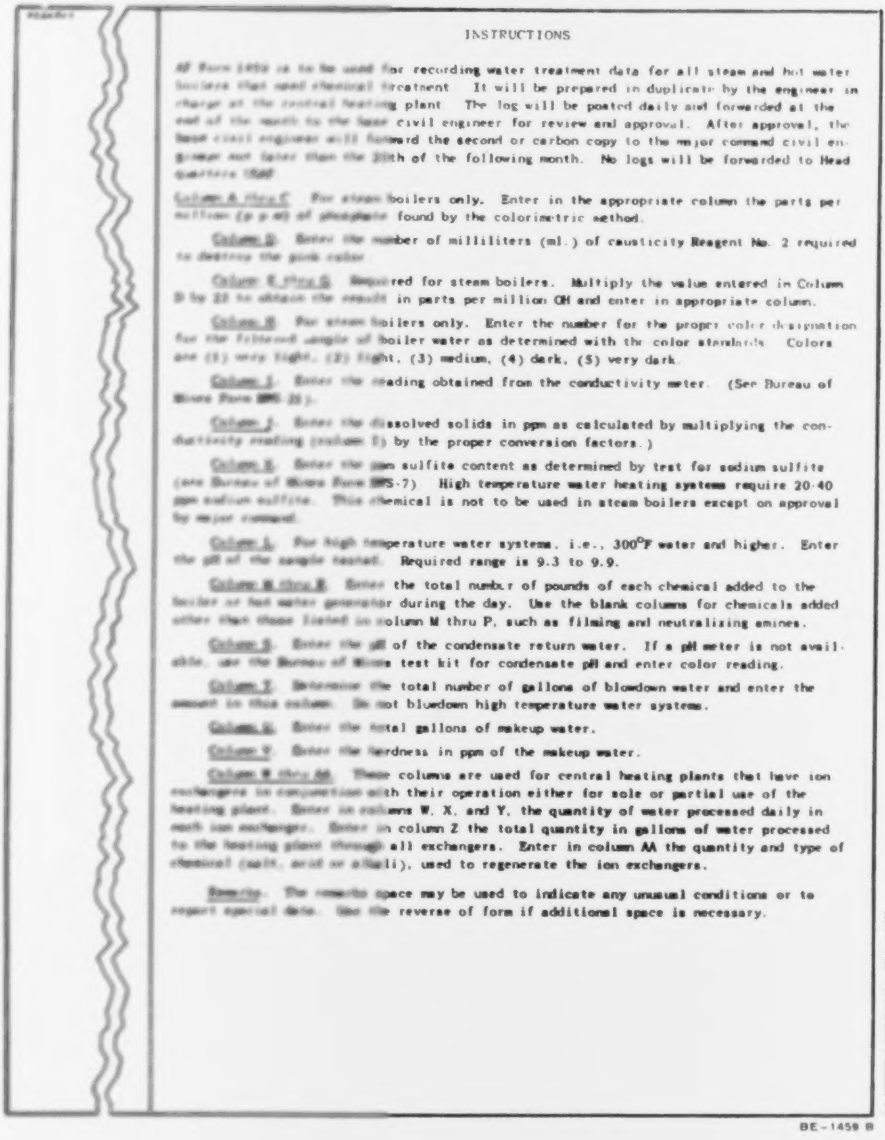
1

June 72

PHOSPHATE NOT AVAILABLE FROM 17 THRU 24 JUNE 72

BEST COPY AVAILABLE

Fig 15. Water Treatment Log



INSTRUCTIONS

AF Form 1459 is to be used for recording water treatment data for all steam and hot water boilers that need chemical treatment. It will be prepared in duplicate by the engineer in charge of the central heating plant. The log will be posted daily and forwarded at the end of the month to the base civil engineer for review and approval. After approval, the base civil engineer will forward the second or carbon copy to the major command civil engineer not later than the [illegible]th of the following month. No logs will be forwarded to Headquarters USAF.

Column A thru C. For steam boilers only. Enter in the appropriate column the parts per million (p p m) of phosphate found by the colorimetric method.

Column D. Enter the number of milliliters (ml.) of causticity Reagent No. 2 required to destroy the pink color.

Column E thru G. Required for steam boilers. Multiply the value entered in Column D by [illegible] to obtain the result in parts per million OH and enter in appropriate column.

Column H. For steam boilers only. Enter the number for the proper color designation for the filtered sample of boiler water as determined with the color standards. Colors are (1) very light, (2) light, (3) medium, (4) dark, (5) very dark.

Column I. Enter the reading obtained from the conductivity meter. (See Bureau of Mines Form BMS-[illegible]).

Column J. Enter the dissolved solids in ppm as calculated by multiplying the conductivity reading (column I) by the proper conversion factors.)

Column K. Enter the ppm sulfite content as determined by test for sodium sulfite (see Bureau of Mines Form BMS-7). High temperature water heating systems require 20-40 ppm sodium sulfite. This chemical is not to be used in steam boilers except on approval by major command.

Column L. For high temperature water systems, i.e., 300°F water and higher. Enter the pH of the sample tested. Required range is 9.3 to 9.9.

Column M thru P. Enter the total number of pounds of each chemical added to the boiler or hot water generator during the day. Use the blank columns for chemicals added other than those listed in column M thru P, such as filming and neutralizing amines.

Column S. Enter the pH of the condensate return water. If a pH meter is not available, use the Bureau of Mines test kit for condensate pH and enter color reading.

Column T. Determine the total number of gallons of blowdown water and enter the amount in this column. Do not blowdown high temperature water systems.

Column U. Enter the total gallons of makeup water.

Column V. Enter the hardness in ppm of the makeup water.

Column W thru AA. These columns are used for central heating plants that have ion exchangers in conjunction with their operation either for sole or partial use of the heating plant. Enter in columns W, X, and Y, the quantity of water processed daily in each ion exchanger. Enter in column Z the total quantity in gallons of water processed to the heating plant through all exchangers. Enter in column AA the quantity and type of chemical (salt, acid or alkali), used to regenerate the ion exchangers.

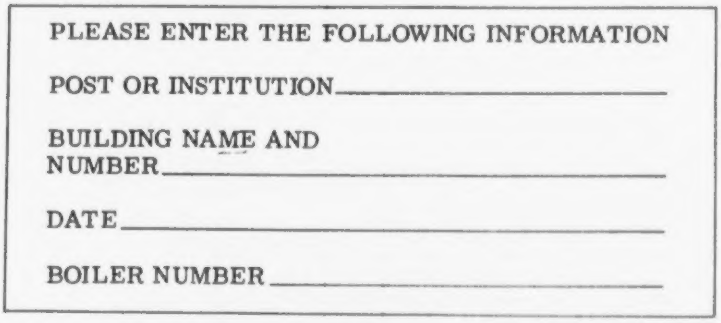
Remarks. The remarks space may be used to indicate any unusual conditions or to report special data. Use the reverse of form if additional space is necessary.

BE-1459 B

Figure 16. Reverse Side of Water Treatment Log

## Labeling the Sample

Water samples are practically useless unless they are properly identified. Many times samples lose their identity in transporting them from the point of collection to the testing laboratory. If the containers are properly labeled, there is less chance for a mix-up in the resulting analysis. Control would be lost if an operator was instructed to treat boiler water based upon water analysis from a diesel engine. Properly labeled water samples also aid the chemist in filling out his reports as he tests the water. Figure 17 shows a typical label for a water sample.



PLEASE ENTER THE FOLLOWING INFORMATION

POST OR INSTITUTION____________________

BUILDING NAME AND
NUMBER____________________

DATE____________________

BOILER NUMBER____________________

Figure 17. Label for Sample Bottle

If you are testing only one sample of water from only one boiler, you may feel it is not necessary to label the sample; but if more than one sample is to be tested, it is quite easy to get the water samples mixed.

Part of the procedure for proper treatment of boiler water entails periodic submission of samples to an adequately equipped laboratory for the purpose of check analysis.

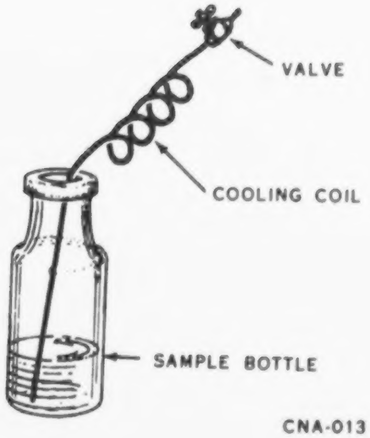
Samples of water from government-operated boiler plants should be sent to the AF Contract Laboratory to be analyzed as directed by AFR 91-7. It is important that you collect a representative sample of boiler water in the prepared containers furnished by the AF Contract Laboratory. The 24-ounce bottle is used for high pressure boilers (above 15 pounds psi) and a 2-ounce polyethylene plastic bottle is used for low-pressure boilers (below 15 pounds psi). See figure 18.

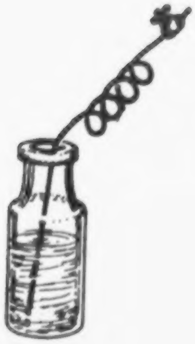
The purpose of the analysis is to help installations engineer operating personnel to correct any faulty analytical techniques and provide a quality check of reagents used for your local analysis.

SUBMISSION SCHEDULE FOR CHECK ANALYSIS. Submit samples for check analysis according to the following schedule:

---- High-Pressure Plants

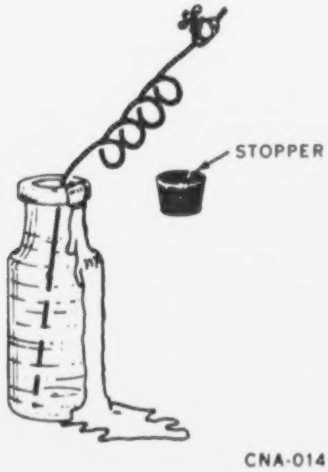
  ---- Each operating plant with high-pressure boilers and one or more boilers of 100 hp or higher: at monthly intervals.

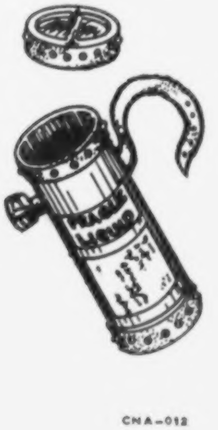

VALVE
COOLING COIL
SAMPLE BOTTLE
CNA-013



a. Blowdown sample lines
b. Rinse equipment
c. Discard rinse water

d. Draw sample slowly
e. Sample line to bottom


STOPPER
CNA-014



f. Overflow bottle
g. Stopper bottle
h. Label bottle

i. Place labeled sample into mailing container for shipment to the AF Contract Lab.

Figure 18. Sending a Sample to AF Contract Lab

---- Each operating boiler plant with high-pressure boilers with less than 100 hp capacity: at three-month intervals. (To even out the sample load and reduce number of containers required, schedule one-third of these plants for each month.)

---- Low-Pressure Plants

---- Each low-pressure steam boiler plant treated with caustic soda: at monthly intervals for individual boilers with a capacity of 100 hp or more; at three-month intervals for individual boilers with a capacity less than 100 hp.

---- Each low-pressure boiler plant, equipped with steel or cast-iron boilers, treated with caustic soda combined with metaphosphate and tannin: at monthly intervals for individual boilers with a capacity of 100 hp or more; at three-month intervals for individual boilers with capacity less than 100 hp.

---- High-Temperature Water Plants (350°F and Above)

---- At monthly intervals.

After filling out the proper forms for High-Pressure Boiler Water Sample, or proper forms for Low-Pressure Boiler Water Samples, place them in the shipping containers with the bottles. Low-presure samples are shipped in a special box provided by the AF Contract Lab. It is a very good safety precaution to tie the straps with a string to prevent "snooping" and tape the corks in to prevent loosening in transit.

ACTION ON BOILER WATER ANALYSIS. The AF Contract Laboratory sends a carbon copy of the boiler water analysis report direct to the base. It sends the original and one copy of the report, with a copy of the base in-plant test, to the appropriate major command (Attn: Civil Engineer Office). In addition to the analysis, this report may contain recommendations for chemical treatment control. Major air command will consider these recommendations in determining corrective action required at the base, but the base will make no major change in treatment solely on the AF Contract Lab recommendations unless directed by the appropriate major air command.

## COMPUTE CHEMICAL DOSAGE TO TREAT BOILER WATER

The initial estimated dosages of chemicals is adjusted to maintain the chemical concentrations within a desired range in accordance with boiler analysis. Changes in operating conditions, such as the boiler load, the amount of makeup water being used, the percentage of condensate being returned, the rate of blowdown, and seasonal changes in the chemical content to the makeup water, cause corresponding changes in the dosages required. The principal variable is the amount of makeup water. The rate of blowdown can be controlled between definite limits. The seasonal changes in the chemical content of the makeup water is usually small. For good chemical dosage control, it is desirable to adjust the chemical feed to the amount of makeup water being used. The results are then checked by boiler water analysis and finer adjustments made in accordance with the chemical excess found. When the percentage of makeup being used does not change very much, it may be more convenient to make the main dosage adjustment in accordance with the steam load instead of the amount of makeup.

### Dosages of Caustic Soda

For the initial dosage of caustic soda, a rough estimate based on the boiler evaporation or the horsepower at which the boiler is operating is generally close enough. To start treatment, about three-fourths (3/4) of a pound of caustic soda can be used for every 3000 pounds of steam produced per hour or for every 100 boiler horsepower. In unusual cases, when the boiler is using a very low percentage of makeup water or using a makeup water which is low in dissolved solids, a smaller initial dosage can be tried.

### Dosage of Sodium Phosphates

The dosage required to treat a given boiler water depends primarily on the total amount of calcium hardness being carried into the boiler by the feedwater. For every pound of calcium, about 1.8 pounds of sodium metaphosphate is required. Where the amount of makeup used in a given period of time is known and there is no appreciable hardness in the condensate, the dosage for that period can be estimated, using the following formula:

$$\text{Dosage of metaphosphate} = \frac{\text{Pounds makeup} \times \text{hardness (Ca) in ppm} \times 1.8}{1{,}000{,}000}$$

Thus, if 150,000 pounds of makeup containing 18 ppm calcium is used, an initial dosage is estimated to be:

$$\frac{150{,}000 \times 18 \times 1.8}{1{,}000{,}000} = 4.9 \text{ lb}$$

Where equipment is not available for measuring the amount of makeup water used, the dosage can be estimated from the boiler load, expressed in horsepower output, the number of hours the load is carried, the calcium hardness in the makeup in parts per million, and an estimate of the percentage of makeup being used as shown in the following formula:

$$\text{Dosage of metaphosphate} = \frac{\text{Horsepower output} \times 30 \times \text{hours} \times \text{percent makeup} \times \text{hardness (Ca)} \times 1.8}{100{,}000{,}000}$$

This formula is based on one horsepower output being equivalent to 30 pounds of steam produced per hour and neglects loss by blowdown. The following example illustrates the use of this formula.

Example: If a boiler plant is operated at 1,000 hp for 8 hours a day and 400 hp the rest of the time, using 20 percent makeup water containing 18 ppm of calcium, an initial daily metaphosphate dosage can be estimated to be:

$$\frac{1{,}000 \text{ X } 30 \text{ X } 8 \text{ X } 20 \text{ X } 18 \text{ X } 1.8}{100{,}000{,}000} + \frac{400 \text{ X } 30 \text{ X } 16 \text{ X } 20 \text{ X } 18 \text{ X } 1.8}{100{,}000{,}000} = 1.6 + 1.2 = 2.8 \text{ lb}$$

Where a steam flowmeter is available which gives the total steam output in pounds in a given time, this value can be used in the above formula in place of the figure for horsepower output X 30 X hours.

If a polyphosphate other than the metaphosphate is used and the $P_2O_5$ content is different, the factor 1.8 would be changed accordingly.

Dosage of Tannin

The concentration of tannin maintained in a boiler is not as definite as the other added chemicals. There is a wide range of concentration in which satisfactory action of the tannin is obtained. One of the most commonly used methods of estimating the initial dosage would be approximately one-half (1/2) pound of tannin per day for every 3000 pounds of steam being produced per hour.

Dosage of Sodium Sulfite

The dosage of sulfite required depends upon the concentration of oxygen in the feedwater and the rate of blowdown.

$$\frac{\text{Lbs of Feed X Oxygen in Feed ppm X } 8.8}{1{,}000{,}000} + \frac{\text{Lbs Feed X \% Blowdown X } 0.3}{1{,}000{,}000}$$

Example: $\frac{456{,}500 \text{ X } 10 \text{ X } 8.8}{1{,}000{,}000} + \frac{456{,}500 \text{ X } 5 \text{ X } 0.3}{1{,}000{,}000}$

Dosage of Neutralizing Amines

When most of the $CO_2$ in the makeup water goes out with the steam, it does with phosphate control, the initial dosage of cyclohexylamine a morpholine can be estimated from the amount of makeup water used and its total $CO_2$ concentrations. Use the following formulas:

Pounds of 60-Percent Cyclohexylamine =

$$\frac{\text{Pounds of Makeup} \times CO_2 \text{ in Makeup in ppm} \times 3.3}{1{,}000{,}000}$$

Pounds of 98-Percent Cyclohexylamine =

$$\frac{\text{Pounds of Makeup} \times CO_2 \text{ in Makeup in ppm} \times 2}{1{,}000{,}000}$$

Pounds of 91-Percent Morpholine =

$$\frac{\text{Pounds of Makeup} \times CO_2 \text{ in Makeup in ppm} \times 2}{1{,}000{,}000}$$

## ADJUSTMENT OF CHEMICAL DOSAGE

The initial estimated dosage is adjusted to maintain the causticity in the desired range, in accordance with boiler-water analysis. Changes in operating conditions, such as the boiler load, the amount of makeup water being used, the percentage of condensate being returned, the rate of blowdown, and seasonal changes, in the chemical content of the makeup water, cause corresponding changes in the dosage required. The principal variable is the amount of makeup water. The rate of blowdown can be controlled between definite limits, and seasonal changes in the chemical content of the makeup water are generally small. For good chemical dosage control, it is therefore desirable to adjust the chemical feed to the amount of makeup being used. The results are then checked by boiler water analysis and finer adjustments made in accordance with the causticity it may be more convenient to make the main dosage adjustment in accordance with the boiler load instead of the amount of makeup.

## SAFE HANDLING OF CHEMICALS

### Handling of Chemicals

PROTECTIVE EQUIPMENT. It is not only your responsibility to obtain protective equipment but also to insure that the quality of the matrial does not deteriorate to a point where it will not provide adequate protection. All personnel should be instructed as to when and how equipment should be used. It is desirable to have a deluge shower installed in an area where chemicals are regularly handled. However, if this is not feasible, there are several antidotes or home remedies such as the use of vinegar and baking soda to neutralize bases and acids that one might accidentally come in contact with. Another common device that can be used to good advantage is the drinking fountain. It provides an emergency method of washing away any chemical coming in contact with the face or eyes. This is NOT a "Do It Yourself Guide" for treatment of chemical burns, but a little first aid before you head for the hospital will sometimes reduce what would be a major injury to a minor one.

MIXING CHEMICALS. There are a few general rules that apply to the mixing of the acids and strong bases that are commonly used in boiler treatment. They are as follows:

---- Never use hot water for mixing acids and strong bases.

---- Always pour the chemical into the water, rather than water into the chemical.

---- Stir constantly while adding chemicals. This will prevent formation of high concentration areas.

### Storage of Chemicals

Chemicals should be identified properly, immediately upon receipt. Do not depend upon the ability of the issue clerk or the rquestor to be able to identify these chemicals at a later date. UNLABELED CHEMICALS ARE AN ACCIDENT LOOKING FOR A PLACE TO HAPPEN. Chemicals should be stacked on pallets or dunnage and should not be stacked higher than chest level to using personnel. Chemicals in metal containers that are to be stored for long periods should have the exterior surfaces thoroughly cleaned prior to storing.

## Chemical Admission to Boilers

When referring to internal treatment, we will limit our discussion to chemicals admitted to the system from a point at or near the suction side of the boiler feed pump up to and including the boiler steam header.

SHOT OR SLUG FEED SYSTEM. These systems are subdivided into pot-type feeders, eductor systems and automatic shot feed arrangements, in which the object of the feeding device is to rapidly introduce a unit charge of chemical treatment. Usually, these systems are employed to avoid feed line deposits that might result from continuous feed. Probably, the oldest method used for the introduction of chemicals is the POT-TYPE FEEDER which consists of a presure tank and fittings. The chemical charge is prepared by dissolving the chemicals in a bucket and then filling the pressure tank with the solution. It is necessary, of course, to drain water from the tank and open the air vent prior to pouring the chemical solution into the tank. Within a few minutes, the solution will be washed out of the pressure tank and will be injected into the boiler, feedwater pressure or flow, boiler feedwater pump suction methods used for transferring chemicals from the feeder to the boiler. The "slug" or "shot" method shown in figure 19 is the adding of a batch of chemicals at one time directly to the boiler. This system is usually satisfactory when the number of "shots" or "slugs" per day does not exceed three or four. If more frequent "shots" are required, it is possible to install a large mixing or dissolving tank to be used in conjunction with pot-type feeders, thus eliminating the inconvenience of dissolving chemicals each time an addition of treatment is necessary. Shot feed systems may be comprised of a timer-operated jump that functions for one ten-minute maximum period each hour.

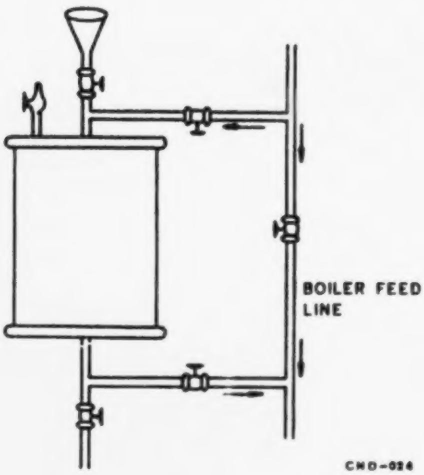


Figure 19. Bypass Feeder for "Slug" Feeding Chemicals

CONSTANT RATE FEEDERS. Constant rate feeders supply a chemical solution at a constant rate of flow, but flow may be intermittent. This type of feeder will vary from a simple drip-type device to a timer-operated controlled volume pump.

PROPORTIONAL FEED SYSTEMS. This type system receives its name from the fact that the amount of chemical supplied to the system is in direct proportion to the rate of supply or discharge. Therefore, it is possible to maintain an exact percentage of chemical in the system at all times. Proportional feed systems range from the simple pot-type feeder, using chemicals in briquette form, to the more elaborate systems such as the General Electric "Thymotrol" system.

## SUMMARY

For economy and longlife of your boiler, you must maintain an AF Form 1459, Water Treatment Operating Log for steam and hot water boilers.

Boiler water samples for the AF Contract Lab should be carefully collected and labeled. (This sample should represent the same water that the operator samples on that day.) Forms should be filled out accurately and shipped the same day.

QUESTIONS

1. What is the purpose of water sample submission to AF Contract Lab?

2. Why is it necessary to label samples as they are drawn?

3. How is a water sample taken from a boiler?

4. What are water sampling coils?

5. Who is responsible for the preparation of the Monthly Water Treatment Log (AF Form 1459)?

6. Where are the instructions found for filling out the log?

7. Why is it important to keep test and water treatment records?

REFERENCES

1. AFM 85-12, Volume I, Operation and Maintenance of Central Heating Plants and Distribution Systems.

2. AFM 85-31, Industrial Water Treatment.

3. AF Form 1459, Water Treatment Operating Log for Steam and Hot Water Boilers.

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## QUESTIONS

1. What is the purpose of water sample submission to AF Contract Lab?

2. Why is it necessary to label samples as they are drawn?

3. How is a water sample taken from a boiler?

4. What are water sampling coils?

5. Who is responsible for the preparation of the Monthly Water Treatment Log (AF Form 1459)?

6. Where are the instructions found for filling out the log?

7. Why is it important to keep test and water treatment records?

## REFERENCES

1. AFM 85-12, Volume I, Operation and Maintenance of Central Heating Plants and Distribution Systems.
2. AFM 85-31, Industrial Water Treatment.
3. AF Form 1459, Water Treatment Operating Log for Steam and Hot Water Boilers.

# EXTERNAL CORROSION

## OBJECTIVE

The purpose of this section of the study guide is to aid you in better understanding corrosion that attacks heating plants and systems.

## INTRODUCTION

Corrosion affects metals by tending to convert metals back to their natural state as ores. Since all of today's Air Force structures and equipment contain or are made of metal, uncontrolled corrosion causes a very rapid failure of these structures or equipment. Boilers and heating systems being made from metals are affected by corrosion and is the cause of frequent and costly heating system failures. Corrosion attack varies on different metals although the basic nature of corrosion is almost always the same. Much of the waste caused by corrosion is due to a lack of knowledge of the subject; therefore, it is important to become familiar with the types of corrosion and their effects on different metals.

## INFORMATION

### TYPES OF CORROSION

There are several different types of corrosion due to difference in metals, metal surfaces, and environment. This study guide will mention the types of corrosion as a list and later on discuss each type more thoroughly as to its source and effect.

Galvanic corrosion
Dissimilar metals
Dezincification
Pitting due to mill scale
Dissimilarity of surface
Dissimilar soil conditions
Different aeration of soil
Concentration cell corrosion
Oxygen cell corrosion
Stray current corrosion
Bacterial corrosion
Active passive cell corrosion
Stress corrosion
Uniform corrosion
Pitting corrosion
Local corrosion
Cracking corrosion
Exfoliation corrosion

### SOURCES OF CORROSION

Sources of corrosion are many and rather hard to pinpoint or classify as sources. The largest source of corrosion comes from the metal involved and its environment. Moisture plays an all important part of corrosion of any metal and when certain impurities found in this moisture are present corrosion is accelerated to unprecedented amounts.

The presence of oxygen is usually essential for serious corrosion in pipelines, boilers, steam generators, and other equipment.

The presence of moisture in the soil causes corrosion to underground structures such as buried pipelines.

Corrosion at normal temperature often increases with the concentration of alkalies, acids, and salts.

Different metals are affected differently with these impurities found in water. Brass usually withstands corrosion well, but with a slight concentration of hydrogen sulfide, it deteriorates rapidly. Aluminum is resistant to many environments, but when this environment contains hydroxides, corrosion of the aluminum progresses rapidly.

### PRINCIPLES OF GALVANIC CORROSION

Below are some of the basic definitions required to understand galvanic corrosion. Additional terms will be used throughout this section and will be defined at that time.

[illegible]. Corrosion is defined in many ways, one being the natural reaction between metals and their environment.

2. Galvanic corrosion is defined as corrosion associated with the current of a galvanic cell made up of dissimilar electrodes.

3. A galvanic cell is a cell make up of two dissimilar conductors in contact with an electrolyte.

4. Electrolyte is a chemical substance or mixture, usually liquid, containing ions which migrate in an electric field and thus conduct electrical current.

5. An anode is the electrode of an electrolytic cell at which oxidation occurs.

6. A cathode is the electrode of an electrolytic cell at which reduction occurs.

7. Oxidation is loss of electrons by an atom or ion.

8. Reduction is the gain of electrons by an atom or ion.

Galvanic Corrosion

When two different conductive materials (known as electrodes) are immersed in a third conductive material (known as the electrolyte), a voltage difference appears between the electrodes. If a connection is made between the electrodes, current will flow from one electrode to the other in accordance with Ohm's law (see figure 20).

This is the principle upon which all batteries are made. The automobile storage battery uses electrodes of lead and lead peroxide in an electrolyte of sulfuric acid. The ordinary dry cell uses electrodes of carbon and zinc in an ammonium chloride electrolyte in paste form.

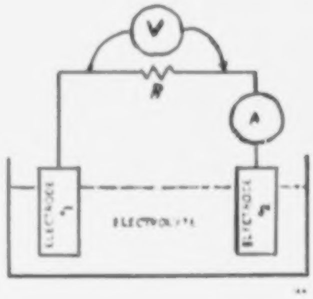

Figure 20. Galvanic Cell

In a galvanic cell (figure 21), current leaves the cell at one electrode (called the cathode), flows through the external circuit and enters at the other elecrode (the anode) and returns to the cathode by flowing through the electrolyte. As the current leaves the anode and enters the electrolyte, some of the anode material changes (becomes ionized) and goes into solution in the electrolyte. This loss of anode material is galvanic corrosion.

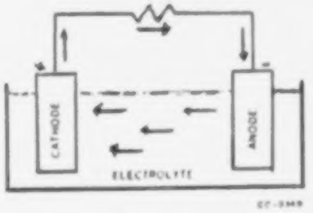

Figure 21. Current Flow in a Galvanic Cell

THE GALVANIC SERIES. The construction of a galvanic cell or battery requires that the electrodes be of two different materials. When these two materials are immersed in the electrolyte and connected externally, current will flow from one to the other, always in the same direction; from + (cathode) to - (anode) in the external circuit, and from - (anode) to + (cathode) in the electrolyte. When two conductive materials are placed in an electrolyte, one will become the cathode and the other will become the anode. The anode-cathode relationship is always the same for any two materials. For example, if iron and magnesium are used as electrodes, iron will always be the cathode and magnesium will always be the anode. However, if iron and copper are placed in an electrolyte, iron becomes the anode and copper becomes the cathode. This means that in the iron-magnesium cell, the magnesium will corrode; while in an iron-copper cell, the iron will corrode. These three metals can be listed in the order of their anode-cathode relationship as follows:

ANODIC OR CORRODED END

Magnesium
Iron
Copper

CATHODIC OR PROTECTED END

indicating that if a magnesium-copper cell were constructed, the magnesium would corrode. This list for a given electrolyte is known as a galvanic series and will tell which of two materials will be the anode and which will be the cathode in that particular electrolyte. A galvanic series for metals in sea water is shown at Table 3. This galvanic series can be used for most situations occurring at Air Force installations.

Table 3. Galvanic Series

| ANODIC OR CORRODED END OF THE SERIES |
|---|
| Magnesium (Galvomag allow) |
| Magnesium (H-1 alloy) |
| Zinc |
| Aluminum (Alclad 3003) |
| Aluminum (3003-H18) |
| Aluminum (6061-T6) |
| Aluminum (5052-H38) |
| Cast Iron |
| Carbon Steel |
| Stainless Steel Type 430, 17% Cr (active) |
| Ni-resist cast iron, 20% Ni |
| Stainless Steel Type 304, 18% Cr, 8% Ni (active) |
| Stainles Steel type 410, 13% Cr (active) |
| Ni-resist cast iron, 30% Ni |
| Ni-resist cast iron, 30% Ni |
| Ni-resist cast iron, 30% Ni + Cu |
| Naval Rolled Brass |
| Yellow Brass |
| Copper |
| Red Brass |
| Composition G Bronze |
| Admiralty Brass |
| 90-10 Cupro-nickel, 0.8% iron |
| 70-30 Cupro-nickel, 0.06% iron |
| 70-30 Cupro-nickel, 0.47% iron |
| Stainless Steel Type 430, 17% Cr (passive) |
| Nickel |
| Stainless Steel Type 316, 18% Cr, 12% Ni, 3% Mo (active) |
| Inconel |
| Stainless Steel Type 410, 13% Cr (passive) |
| Titanium (commercial) |
| Silver |
| Titanium (high purity from iodide) |
| Stainless Steel Type 304, 18% Cr, 8% Ni (passive) |
| Hastelloy C |
| Monel |
| Stainless Steel Type 316, 18% Cr, 12% Ni, 3% Mo (passive) |
| CATHODIC OR PROTECTED END OF THE SERIES |

Table 3 shows that magnesium will corrode and therefore protect steel, that steel will corrode and protect copper; and that copper in turn will protect silver.

THE ELECTROLYTIC CELL. The electrolytic cell is similar to the galvanic cell, except that the electrode materials can be either the same, or so close in the galvanic series that voltage difference (and corrosion) is extremely small. In this type of cell, the voltage is provided by an outside source and the electrode polarity is reversed.

In the electrolytic cell, the anode-cathode relationship is determined by the polarity of the dc current source. If the polarity of the source is reversed, the cathode will become the anode and the anode will become the cathode. This happens in an automobile when the generator is charging the battery. It is possible to change a galvanic cell into an electrolytic cell by inserting a dc source into the circuit and reversing the normal galvanic anode-cathode relationship and causing the electrode that formerly corroded to be protected. This is the basis for the impressed current systems of cathodic protection (see figure 22).

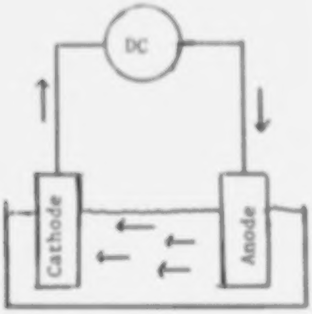

Figure 22. Current Flow in an Electrolytic Cell

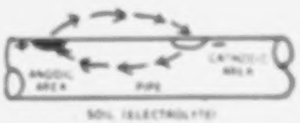

Figure 23. Current Flow in a Concentration Cell

THE CONCENTRATION CELL. A concentration cell is formed by electrodes of the same material in an electrolyte of varying composition (different environment). Typical concentration cells are formed on the surfaces of buried metal (such as a pipe) where the moist soil serves as the electrolyte. Concentration cells may be formed by many types of changes in electrolytes. For example: variations in the amount of oxygen in the soil, changes in moisture content, or changes in soil types may set up concentration cells and cause corrosion of underground structures (see figure 23).

RATES OF CORROSION. Electrochemical corrosion takes place in accordance with Faraday's law; that is, 26.8 ampere-hours will remove one gram-equivalent-weight of metal. Table 4 lists common structural metals and the weight loss which would be due to a current of one ampere flowing for one year.

Table 4. Electrochemical Equivalents of Common Structural Metals

| Metal | Weight Loss Pounds per Ampere-Year |
|---|---|
| Iron | 20.1 |
| Aluminum | 6.5 |
| Lead | 74.5 |
| Copper | 22.8 |
| Zinc | 23.6 |
| Magnesium | 8.8 |
| Nickel | 21.1 |
| Tin | 42.0 |
| Silver | 77.6 |
| Carbon | 2.2 |

## PRACTICAL ASPECTS OF ELECTROCHEMICAL CORROSION

### Corrosion of Metal in the Ground

Any type of metal structure in contact with moist earth can be subject to electrochemical corrosion. The structures usually thought of in this respect are:

Pipelines (water, gas, fuel, steam, etc.)
Tanks (water, fuel)
Piling (sheet and H) + Pipe
Cables and electrical conduits

GALVANIC CORROSION may be set up where dissimilar metals can form a galvanic cell. For example, a copper water service line and a steel gas service line are buried in the ground are connected to a hot water heater. In this case, current leaves the gasline (anode) corroding the steel, and flows through the earth to the copper waterline (cathode) and back to the steel pipe through the hot water heater.

ELECTROLYTIC CORROSION is a result of the formation of an electrolytic cell by stray dc electric current.

CONCENTRATION CELL CORROSION is probably the most common type of corrosion occurring on buried structures. It is caused by local, and sometimes minute, variations in soil makeup. The effects of this type of corrosion vary from light general corrosion to severe local pitting and metal loss depending on soil and moisture conditions.

### Corrosion of Metals in Water

Metals in contact with electrically conductive water also corrode electrochemically.

Structures subject to corrosion under these conditions are:

Water Storage Tanks
Evaporative Condenser and Cooling Tower Sumps
Evaporative Cooler Pans
Hot Water Tanks
Sheet Pile Retaining Walls (along waterways)

Corrosion in water is due to a combination of galvanic and concentration-cell corrosion.

No metal can be made exactly the same throughout. There are always small variations in the makeup of a metal sheet or plate due to flaws in the material, differences in crystal structure, or uneven mixing of alloying materials. These minute differences in the metal are enough to set up tiny galvanic cells when the surface is covered with water. Under static conditions (when the water is not moving) changes in the concentration of dissolved solids in the water aggravates the rate of galvanic corrosion. The rate of corrosion is greatly influenced by the ability of thewater to conduct electricity. It is for this reason that corrosion is much more rapid in sea water than in fresh water.

### Corrosion Caused by Dissimilar Metals

In this type of corrosion, the metal highest on the emf series becomes the anode. The electrolyte may be the water carried inside of the pipe resulting in internal corrosion. It may also be in the form of moisture or damp soil on the external surface of the pipe. Often, it is caused by placing dissimilar metals together as in figure 24.

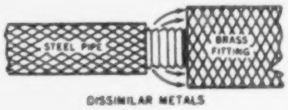

Figure 24. Corrosion Caused by Dissimilar Metals

### Dezincification

Dezincification is a phenomenon of corrosion that is limited to the brasses--an alloy made up of copper and zinc (see figure 25). As the name implies, zinc is lost from the alloy by going into solution leaving as a residue, or by a process of redeposition, a porous mass of copper having little mechanical strength. Dezincification may be easily observed since attached areas show the color of copper as compared to the very distinctive yellow of brass.

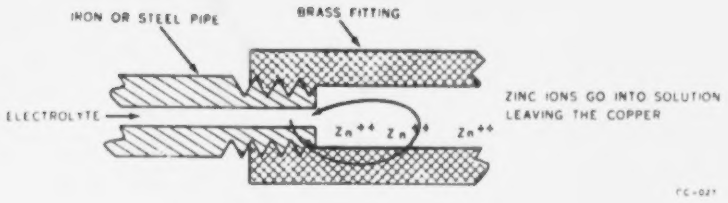
IRON OR STEEL PIPE
BRASS FITTING
ELECTROLYTE
$Zn^{++}$ $Zn^{++}$ $Zn^{++}$
ZINC IONS GO INTO SOLUTION LEAVING THE COPPER

Figure 25. Dezincification

## Pitting Due to Mill Scale

In the manufacture of pipe, mill scale becomes embedded in the pipe walls. The mill scale embedded in the iron pipe constitutes two dissimilar metals. The moist soil acts as an electrolyte. Current leaves the iron pipe wall, passes through the electrolytic soil to the mill scale and returns to the pipe metal. This causes severe pitting of the pipe metal at the anodic areas (see figure 26).

NOTE: Mill scale magnetic oxide of iron formed on steel whenever hammered or rolled in a heated condition is removed by "pickling" in sulfuric acid.

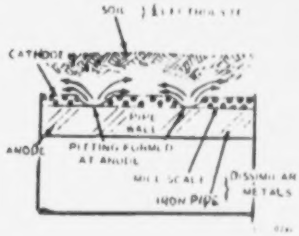
SOIL } ELECTROLYTE
CATHODE
PIPE WALL
ANODE
PITTING FORMED AT ANODE
MILL SCALE
IRON PIPE
DISSIMILAR METALS

Figure 26. Pitting Due to Mill Scale

## Corrosion Caused by Dissimilarity of Surface

This type of corrosion occurs when there is bright or polished surfaces on some areas of the pipe walls in contact with a suitable electrolytic soil. These bright surfaces become anodic to the remaining pipe surface. In a high ionized soil, the polished surfaces corrode at an accelerated rate, weakening the pipe at that point. These bright surfaces may be made by a pipe wrench producing scars and scratches or by sharp edges of rocks when backfilling. The threads on both sides of a coupling may expose bright surfaces which corrode easily. Corrosion in the threads can produce the added difficulty of causing perforation of the pipe wall (see figure 27).

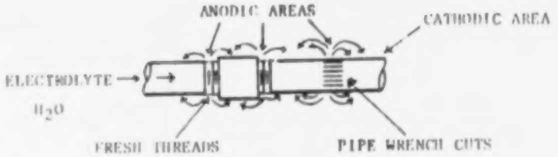
ANODIC AREAS
CATHODIC AREA
ELECTROLYTE
$H_2O$
FRESH THREADS
PIPE WRENCH CUTS

Figure 27. Corrosion Caused by Dissimilarity of Surface

## Corrosion Due to Dissimilar Soil Conditions

Figures 28 and 29 show galvanic action due to dissimilar or different soil conditions. This is a general corrosion problem especially prevalent in highly alkaline areas. Corrosion currents leave the pipe wall into compact soils and enter the pipe wall from light sandy soils. The intensity of the corrosive currents and the resulting rate of corrosion at the anodic areas of the piping are directly proportional to the conductivity of the soil. Earth current meters are used to determine the location of the anodic and cathodic areas and the extent corrosive currents exist. This meter determines if piping requires protection.

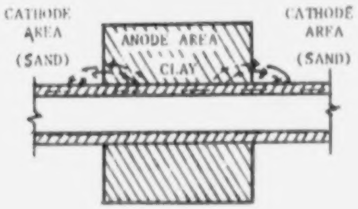

Figure 28. Corrosion Caused by Dissimilar Solids

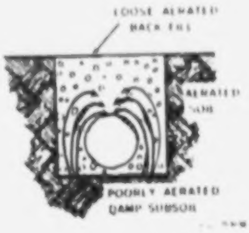

Figure 29. Corrosion Caused by Differential Aeration of Soil

Corrosion Due to Differential Aeration of Soil

In figure 29, the galvanic cell which produces corrosion is caused by differential aeration of soil in backfill. This type of corrosion is the result of an electrochemical reaction between the damp solid ground on which the pipe rests and the loose drier backfill which surrounds the pipe. This condition results in severe pitting on the bottom of the pipe.

Concentration Cell Corrosion

As noted previously, ions of a metal will be given up at the metal's surface to enter into solution. Whenever a higher metal-ion concentration exists in one region more than in another, an electrical potential is created between these areas. The one having the higher ion concentration is cathodic (see figure 30. A typical example of metal-ion cell corrosion may be found around riveted lap joints. Such reaction is caused by the relatively high-ion concentrations in fairly stagnant areas within the lap joint. Corrosion of this type is usually found at the outer edges of joints or deposits since the off stated electrochmical action will try to make the concentrations uniform by forcing metal into solution at the point of lower concentration.

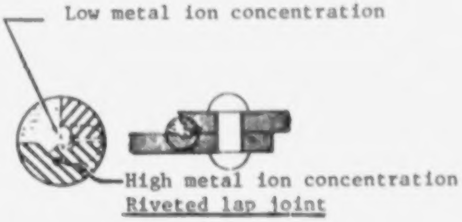

Figure 30. Concentration Cell Corrosion--Metal Ion Type

Corrosive attack in areas of breakthrough of the protective coatings, such as paint, sealers, protective oils, and greases, is another form of metal ion concentration cell. Also included in this would be oxide films of the metal and inhibitor films.

### Oxygen Cell corrosion

Figure 31 illustrates oxygen cell corrosion which occurs when a solution contains varying amounts of dissolved oxygen. A deposit, crevice or sharp corner that prevents the diffusion of air into these areas will result in a difference of oxygen dissolved in the solution. In this case, current leaves the metal at the region of lowest oxygen concentration, passes through the electrolyte, and enters the metal again at the area having the higher concentration of oxygen. It should be noted that the metal ion cell and the oxygen cell oppose each other and the area of corrosion is determined by which cell is stronger.

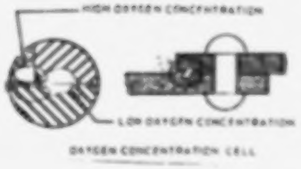

Figure 31. Concentration Cell Corrosion--Oxygen Cell Type

### Stray Current Corrosion

Figure 32 illustrates stray current corrosion. Pipelines in the vicinity of electric transportation systems, electrified coal mines or manufacturing plants are subject to this type of corrosion. This type of corrosion exists where direct current uses ground return for a complete or partial return. If any metallic structure such as a tank or pipeline is laid in such an area, a large galvanic cell is created. Corrosion does not occur at the point where the current enters the structure because it is cathodically protected. However, at the section where the current leaves the pipe, severe stray current corrosion occurs. Over a period of a year, this type of corrosion has been known to displace as much as twenty pounds of pipe wall for every ampere. There are various types of cathodic protection that are used to combat this stray current corrosion.

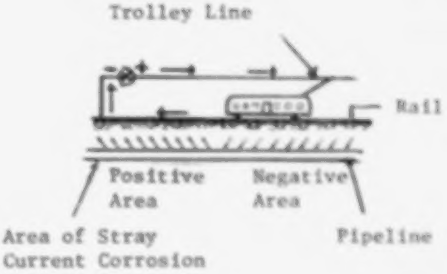

Figure 32. Stray Current Type Corrosion

### Bacterial Corrosion

Bacterial corrosion is another distinct type of corrosion resulting from electrolytic or galvanic cell action of biological organisms. By definition, bacterial corrosion is the deterioration of metals by corrosion processes which occur as either a direct or an indirect result of the metabolic activity of certain bacteria, particularly in water or soil environments. These biological organisms causing bacterial or biological corrosion are bacteria, slime, and fungi. Microbiological corrosive action in the soil is due to physical and chemical changes of the soil by the action of these organisms. Some types of aerobic bacteria are responsible for the production of active galvanic cells. These cells are produced by production of variations of oxygen content in the soil (differential aeration) or the reduction of the hydrogen film over the cathodic areas (depolarization). Anerobic bacteria are responsible for the reduction of sulfate salts into sulfide compounds. As already studied, sulfides like hydrogen sulfide vigorously attack most metals. Anaerobic bacteria are mostly found in highly water logged, sulfate bearing, blue clay type soils. The bacteria concentration as well as the corrosion rate varies considerably between the different seasons of the year. Cast iron and steel piping are corroded mostly by sulfide production.

### Active Passive Cell Corrosion

This type of corrosion is similar to the oxygen cell corrosion but is more powerful. It is found on metals that normally have a passive film acting as a corrosion protector. Stainless steel is a good example of this type of metal. The metals in question usually form a protective oxide film that is impervious to corrosion attack. This film is automatically repaired when any breakthrough of the film occurs should sufficient oxygen be present. However, there are some conditions that may exist whereby the film cannot be repaired and the metal surface turns active. Should oxygen be absent from the electrolyte as within a crevice or under some deposit, the normally passive metal would favor an active state for the hidden areas. The area that is protected by the oxygen concentration acts as a cathodic area in relation to the active (anodic) area. Referring to Table 1, the difference between a metal's active and passive state may be observed in the galvanic series.

### Stress Corrosion

Stress corrosion is considered to be an acceleration in the rate of corrosion due to a static stress; a combination mechanical-electrochemical type of corrosion. This type of corrosion is concerned with the failure of a metal part due to the combined action of stress and corrosion and is restricted to the situations where no significant amount of corrosion is found without the presence of stress. Stress corrosion cracks develop in a plan perpendicular to the direction of stress action. These stresses are either externally or internally formed. External stresses are the result of a tensile load applied to the structure while internal stresses may be caused by any number of reasons such as improper heat treatment, rivet holes, stamping of metal and welding. It is important to remember that any cleaning should be limited to the removal of corrosion products and none of the metal in these stressed areas.

The above types of corrosion result in different forms of metal removal.

### Uniform Corrosion

This is the most common form of corrosion and represents the greatest destruction of metal on a tonnage basis. It is characterized by an electrochemical action which proceeds uniformly over the entire exposed surface. The metal becomes progressively thinner until a point is reached where it is no longer of any use. In this type of reaction, those areas that are anodes initially corrode and then become cathodes due to the layer of corrosive material. The area that was a cathode initially becomes anodic to the layer of corrosive material. These anodic and cathodic areas change back and forth continually, resulting in a somewhat uniform removal of the metal.

### Pitting Corrosion

This is one of the most destructive forms of corrosion. The destruction of the metal is not associated with a large weight loss as uniform corrosion but it is characterized by an irregular surface destruction in a localized form of corrosion. The attack is limited to extremely small areas of the metal surface while the remaining surface is not affected. In fact, the term pitting is used when localized attack takes place with the width being on the same order or less than the depth. Probably more unexpected part failure may be traced to pitting than any other form of corrosion. One pit in a relatively uncorroded pipeline or storage tank can cause that structure to be out of service until repaired.

### Local Corrosion

Type of corrosion caused by local action or local galvanic cells. It is that form of corrosion that is between uniform corrosion and pitting. It may be a local area of uniform corrosion while not corroding over the entire surface. Or it may take the form of uneven corrosion in a certain locality.

### Cracking Corrosion

This form of corrosion is normally encountered in stress corrosion. As the name implies, it is depicted by a crack extending across the metal accompanied by a penetration of the metal.

### Exfoliation Corrosion

This form of corrosion causes the scaling off of a metal surface in flakes or layers. It is a form of intergranular corrosion and shows itself by "lifting up" the surface grains of a metal by the force of expanding corrosion products occurring at the grain boundaries just below the surface.

## PREVENTION OF CORROSION

There are several methods of combating corrosion and these may be listed as follows:

1. **Material selection**
2. Design practices
3. Isolate metal from environment
4. Alter environment

### Material Selection

In selecting materials, especially where connections or couplings of dissimilar metals are to be made, Table 1 should be a good guide.

If it becomes necessary to connect dissimilar metals in a piping or other systems, the anode should be large compared to the cathode. This would allow more dispersion of the corroding current over the anodic area and also easier polarization of the cathode. In another case, let us consider the iron or steel nipple screwed to a brass valve. If corrosion cannot be prevented, it would be more suitable to use an extra heavy nipple in place of the standard nipple. Although the corrosion would not be prevented, the system would remain in operation longer before the nipple was corroded beyond use.

### Design Practices

Utilization of a few basic design principles may aid in the prevention of corrosion. An example of this is illustrated in figure 33.

This type of trap may be encountered when nipples are screwed into a tank and extend beyond the inside surface of the tank, thus trapping water.

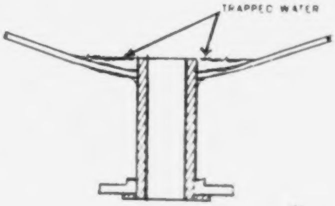

Figure 33. Improper Drain Design Whic[illegible] Allows Trapping of Moisture

### Isolation of Metal

There are many ways of isolating the metal from the corroding environment. These may be classified under one of the following general categories:

1. Metallic
2. Inorganic
3. Organic

Metallic coating as an insulator covers a wide range of applications. Such metals as chromium, nickel, and copper may be electroplated to some base metal as a form of protection. Galvanized iron is an example. Another method is flame-sprayed metal coatings. Here, metal wire or powder is melted in a gas flame and projected by compressed air onto a metal surface. Cladding is still another form of metallic coating used in corrosion control. Basically clad is applied by hot rolling. One example of this would be a cladding of pure aluminum over an aluminum alloy surface. Oxide films may also be placed in this category. In this case, a thin corrosive film is desired to act as a barrier.

Inorganic coatings, other than metallic ones, include such products as glass, enamels, and other ceramic coatings.

Organic coatings such as paints, varnishes, lacquers, and similar materials probably protect more metal than any other method used. In the application of these various coatings, surface preparation and proper application are very important. There are usually industry or government standards available on the correct procedures involved. These specification should be followed to the letter when possible for they represent a great amount of research and experience. The effectiveness of the coating depends not only on its moistureproof quality but also on its ability to adhere and its own immunity to the corroding environment.

## SELECTION OF COATINGS

### Underwater Exposure, Interiors of Storage Tanks and Water Pipes

1. Hot-applied, coal-tar coatings are used extensively because these materials have low moisture absorption and are virtually unaffected by long periods of immersion in water. Coal-tar pitch is good up to a temperature range of 125° to 140°F and is used principally for coating irregularly-shaped objects by dipping where these objects are difficult to paint by conventional brushing and spraying methods. Coal-tar enamel is considered an excellent coating for the interior surfaces of all steel pipe and for the exterior surfaces for buried pipe. However, the materials marketed are not expected to withstand temperatures under -20°F without danger of cracking and disbonding.

2. Cold applied plastic tapes such as spirally wound vinyl and polythylene tapes are under investigation.

3. Cold-applied, coal-tar coatings containing solvents can be applied, without heating, by ordinary brush and spray methods. These paints adhere tenaciously to properly cleaned metal surfaces and are able to withstand cold without damage. The primary use would be where the coating job is too small to warrant the expense of setting up equipment for applying hot coal-tar coatings.

4. Vinyl and phenolic paints have been specified for the interior of steel pipe which will be empty in winter and subjected to temperatures below -20°F, the lower limit for coal tar enamels. Three coats of phenolic red lead paint are specified.

5. Cement mortar, pneumatically applied, is used on the exterior surfaces of large diameter steel pipe used in a water-submerged crossing. It may be applied as supplemental protection over the exterior surfaces of coal-tar enamel, especially where the pipe is to be buried in rocky terrain and suitable backfill is not readily available. Cement mortar is also used as a protective interior lining for steel and cast-iron pipe, both new and old.

6. Asphalt coatings, hot-dip, is sometimes used for small-diameter (under 24 inches) steel pipe but is not generally considered to be as effective as coal-tar coating for protection of steel pipe against corrosion.

### Air and Water Exposure

Vinyl-resin paints are characterized by their inertness to water and many chemical solutions. These paints are stable under exposure to sunlight and are not adversely affected by extremes in atmospheric temperatures. This paint is recommended for metal work where there may be a spillage of acids or alkalies.

### Atmospheric Exposure

1. Priming paints such as red lead primer have been used many years with very satisfactory results for metal work exposed to weather. Zinc chromate (zinc yellow) has also been found to be an excellent pigment for metal primers. Both have rust inhibitive properties which are important in preventing rust development beneath the paint film and in preventing rust creep at areas where the film has been scratched or gouged through to bare metal.

2. Aluminum finish paint is exceptionally well suited for use in top coats of paint on metal work exposed for weathering. A combination of pipe or structure coating and cathodic protection is in wide use as this lowers the amount of cathodic protection required and the cathodic protection in turn protects any "holiday" in the coating material. Other isolating material may be plastic or rubber lining inside a metal storage tank.

## ALTERING ENVIRONMENT

Very often, the electrolyte can be altered and thus reduce its corrosiveness. Such factors as dissoved oxygen, temperature, pH, chemical composition of the solution, etc., may be altered to provide a more suitable existence for the metal to be protected. The use of inhibitors such as sodium phosphate or potassium chromate alter the environment or provide a protective film to protect the metal.

Corrosion always occurs at the anode of a cell. When this anode is a pipeline, tank, or other engineering structure, its useful life is shortened and the maximum value of the original investment cannot be realized. It is possible to apply the principles of electrochemistry and change the structure into the cathode of a cell (hence, the name cathodic protection) and reduce or prevent this electrochemical corrosion. There are two general types of cathodic protection systems:

### Impressed Current Systems

Impressed current systems utilize an external source of dc current to set up an electrolytic cell with the protected structure as the cathode of this cell. The designer of the system may choose the anode he wishes. Commonly, anodes for impressed current systems are made of graphite or high-silicon cast iron (known as Duriron) because these materials have very low rates of weight loss per ampere-year of use. Scrap iron rails, old engine blocks, and the like have been used, but the rate of weight loss for iron is quite high and this type anode corrodes away rather quickly. Any source of dc current may be used to set up the electrolytic cell action in an impressed current system. Early practice used batteries, dc generators and tungar rectifiers. These systems have largely been superseded by modern selenium and silicon rectifiers.

When the impressed current method is used, a direct current from an external source is forced from the ground bed through the electrolyte to the metal to be protected. The ground bed consists of anodes either submerged in the electrolyte or buried in the ground. The material used as anodes in an impressed current system would not corrode alone. They corrode only when the current from the external current source is connected to the structure that is to be protected, and the positive side is connected to the anodes in the ground bed (see figures 34 and 35).

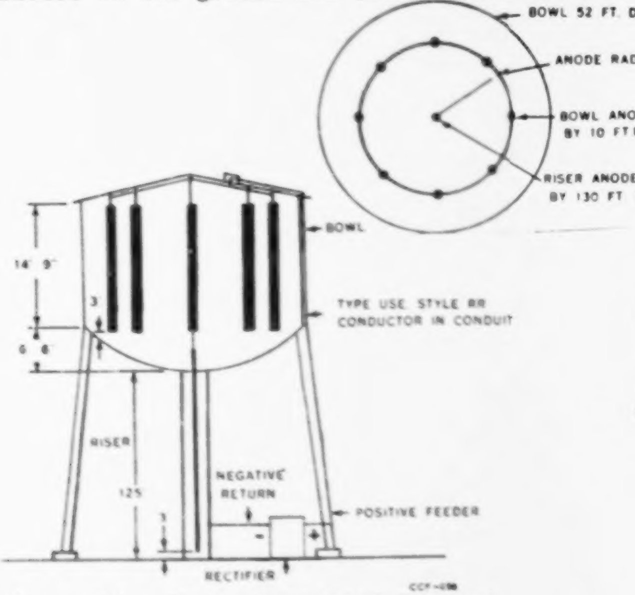
BOWL 52 FT. DIAMETER
ANODE RADIUS 18 FT.
BOWL ANODES -1 IN DIAMETER BY 10 FT LONG -ALUMINUM
RISER ANODE 1 2 IN. DIAMETER BY 130 FT. LONG-ALUMINUM
BOWL
14' 9"
3'
6' 6"
TYPE USE STYLE RR CONDUCTOR IN CONDUIT
RISER
125'
3'
NEGATIVE RETURN
POSITIVE FEEDER
-
+
RECTIFIER
CCP-086

Figure 34. Using Impressed Current Protect a Water Storage Tank

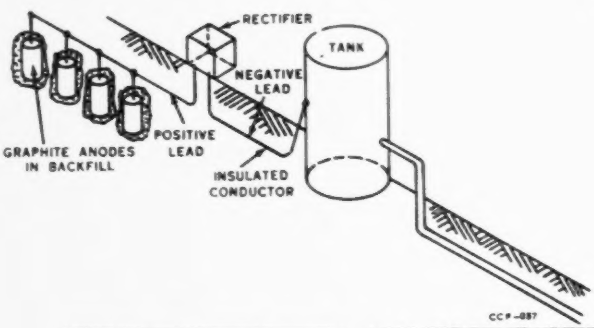
RECTIFIER
TANK
NEGATIVE LEAD
POSITIVE LEAD
GRAPHITE ANODES IN BACKFILL
INSULATED CONDUCTOR
CCP-087

Figure 35. Using Impressed Current to Protect a Pipeline

### Sacrificial Anode Systems

Sacrificial anode systems set up a galvanic cell with the protected system as the cathode and a less noble material (nearer the corroded end of the galvanic series in Table 3) as the anode. Because the anodes corrode and waste away to protect the desired structure, these systems are known as sacrificial anode systems. Sacrificial anodes are usually of zinc or magnesium. The choice of material depends on the cost, method of construction and character of the electrolyte (soil or water) involved. Aluminum, although less noble than iron or steel is not far enough away in the galvanic series to be fully effective in setting up a galvanic cell for protective purposes. Aluminum is used however, as a sacrificial anode in impressed current systems to protect the interior surfaces of water standpipes and storage tanks.

To accomplish cathodic protection by the galvanic method, a metal that will corrode is placed into the electrolyte and electrically connected to the structure that is to be protected. A metal that is more active and less expensive than the metal that is to be protected is connected to the metal for which protection is desired. Magnesium or zinc is generally used to protect iron or steel structures. Electric current will then flow from the corroding metal through the electrolyte to the metal for which protection is desired. The electrical connection between the two objects completes the circuit and allows the current to return to the corroding metal. The corroding metal becomes the anode of a purposely established dissimilar metal cell and the metal to be protected becomes the cathode. The corroding metal becomes the anode and the protected metal becomes the cathode of a corrosion cell. If the current from the corroding metal (anode) is strong enough to prevent all current from leaving what was determined to be the anodes of the metal, the anodic area will disappear and corrosion will stop (see figure 36).

Impressed current systems use a rectifier to protect the pipe or tank by forcing currents to leave an anode bed and enter the metal and protect it. The positive side of the rectifier is connected to the anode bed and the negative side is connected to the structure. All wires, splices, and junctions on the positive side must be protected by waterproof insulation. The best insulation for splices on the wire is thermal-setting epoxy plastic. The anode bed uses graphite, stainless steel, high silica cast iron or in some cases aluminum anodes.

SUMMARY

A knowledge of the action of galvanic corrosion should aid you in combating this type of destruction. The electrochemical action for galvanic corrosion requires four things: (1) anode, (2) cathode, (3) electrolyte, and (4) path of low electrical resistance. It should be remembered that where the conventional or positive current leaves the metal and enters the electrolyte, the metal will corrode. Where the current leaves the electrolyte and enters the metal, the metal will not corrode.

Although the principle of galvanic corrosion is basic, this type of corrosion exists under many different situations. The connection of two dissimilar metals, even two different types of stainless steel, is one of the primary causes of galvanic corrosion. Another example is where old pipe is connected to new pipe. One large concern had to replace a section of pipeline because it had corroded through. This section was replaced with new pipe, and corroded through in a relatively short period of time. Their comment at the time was naturally, "They are not making pipe nowadays as good as they used to make it." However, we know now that the new pipe had become anodic to the old pipe and that this particular section of pipe was also located in a very corrosive soil.

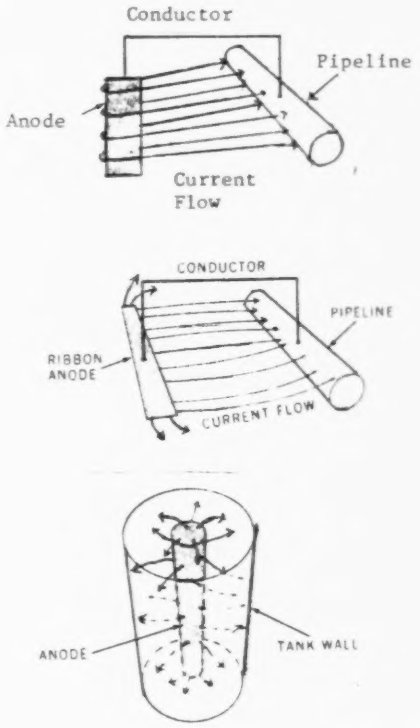

Figure 36. Magnesium Anodes Used to Protect Metallic Structures

Several methods can be used to eliminate or reduce this galvanic corrosion. Proper selection of materials and design practices are primarily the job of the design personnel. However, modifications and repairs on the structure should take these items into consideration. Probably the most important protection is obtained by protective coatings such as tar or paints used in maintaining the structures. These should be properly applied to be effective. Other methods such as linings or changing the chemical characteristics of the electrolyte are possible.

Cathodic protection is applied to both bare metal surfaces and to painted or otherwise coated surfaces. Since the amount of current required for protection is proportional to the area exposed to the electrolyte, much less current is required to protect a coated surface. The coating on a structure will pay for itself most of the time.

Corrosion is often concentrated at breaks in the coating, making it necessary to repair the coating. The two methods of applying coating are the hot coating method a the cold coating method. The hot coating method has proven to be much more satisfactory.

REFERENCES

1. AFM 85-5, Maintenance and Operation of Cathodic Protective Systems
2. AFM 85-12, Vol I, Operation and Maintenance of Central Heating Plants and Distribution Systems

WORKBOOKS

J3ABR54532 001-VIII-1 thru VIII-5

Technical Training

Heating Systems Specialist

# BOILER WATER TREATMENT AND CORROSION CONTROL

June 1984

3700 TECHICAL TRAINING WING
3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

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| VIII-3 | Internal Treatment | 3-1 |
| VIII-4 | Logs and Chemical Feeding | 4-1 |
| VIII-5 | External Corrosion | 5-1 |

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Supersedes WBs J3ABR54532 001-VIII-1 thru VIII-5, May 1983. (Copies of the superseded publication may be used until supply is exhausted.)

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

WB J3ABR54532 001-VIII-1

## SOURCES OF WATER

### OBJECTIVE

Given information, explain basic facts about sources of water and their characteristics with 80% accuracy.

### PROCEDURE

1. Get out pen or pencil, workbook and study guide.

2. When directed to do so by the instructor, complete the questions.

   a. List the four sources of water.

      (1) ____________________

      (2) ____________________

      (3) ____________________

      (4) ____________________

   b. Where would collected water be used?

      ____________________

      ____________________

   c. Why is seawater not normally used?

      ____________________

      ____________________

   d. Two types of impurities found in water are ____________________ and ____________________.

   e. List three types of suspended impurities.

      (1) ____________________

      (2) ____________________

      (3) ____________________

f. List two impurities in water which cause hardness.

(1) ____________________

(2) ____________________

g. List three impurities in water which cause an alkaline condition.

(1) ____________________

(2) ____________________

(3) ____________________

h. Which dissolved gas in water causes corrosion in condensate lines?

____________________

i. Which dissolved gas in water causes pitting to boiler surfaces?

____________________

j. The main effect of excessive impurities in water is

____________________.

k. Two types of carryover are ____________________ and

____________________.

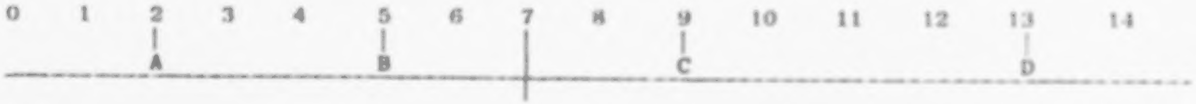
l. Heavy concentrations of sodium hydroxide can cause ____________________

____________________.

m. If the make-up rate increases, the amount of impurities entering the boiler is

____________________.

4. Using the pH scale listed below, complete questions.



a. Of A, B, C and D, which is slightly alkaline?

____________________

b. Of A, B, C and D, which is the strongest acid?

____________________

c. State the purpose of the pH scale.

______________________________________________________________

______________________________________________________________

______________________________________________________________

d. What is boiler scale?

______________________________________________________________

______________________________________________________________

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

WB J3ABR54532 001-VIII-2

# EXTERNAL TREATMENT

## OBJECTIVES

Given information, determine step-by-step procedures for installation, operation, and servicing of external water treatment equipment with 80% accuracy.

Given information and equipment, service and operate demineralizing equipment with instructor assistance.

Using the soap solution and EDTA water testing equipment, test a given water sample for hardness with instructor assistance.

## PROCEDURES

1. Get out pen or pencil, study guide and workbook.

2. This workbook is divided into three exercises: Exercise 1 -- Removing Dissolved Impurities; Exercise 2 -- Zeolite Softener Operation; and Exercise 3 -- Water Hardness Tests.

3. Complete questions in Exercise 1 for directed study assignment.

4. Proceed to training area and run softener through a complete cycle, as directed in Exercise 2.

5. Upon completion of Exercise 2, proceed to lab area and complete Exercise 3.

## EXERCISE 1

### Removing Dissolved Impurities

1. What is external boiler water treatment?

______________________________________________

2. What are two methods of softening water, using the ion exchange principle?

a. ______________________________________________

b. ______________________________________________

3. Ion exchange is the process of exchanging ion of ______________________

and/or ______________________ for ions of ______________________

or ______________________.

4. The effluent of a sodium zeolite ion exchanger would be ______________________

and slightly ______________________.

5. Would the pH of the water leaving a hydrogen zeolite ion exchanger be higher or lower than the influent?

______________________________________________

6. List the four elements used by chemists to produce synthetic zeolites.

a. ______________________________________________

b. ______________________________________________

c. ______________________________________________

d. ______________________________________________

7. Briefly explain what occurs in the chemical precipitation water softening process.

______________________________________________

______________________________________________

______________________________________________

8. List two methods of chemical precipitation water softening.

a. ______________________________________________

b. ______________________________________________

9. At what temperature does the hot lime soda process of water softening operate?

______________________________________________

10. List two methods of removing undesirable gases from water.

a. ____________________________________________

b. ____________________________________________

11. Deaeration is employed for what purpose?

______________________________________________

12. Bringing water to the boiling point will remove what percentage of free oxygen?

______________________________________________

13. Pitting in boilers is caused by ______________________________.

14. Direct acid treatment of boiler feedwater is necessary to reduce or correct

______________________________________________

______________________________________________.

15. Corrosive gases such as ____________________ and ____________________ are classified as dissolved impurities.

## EXERCISE 2

## Zeolite Softener Operation

### Manually Operated Zeolite Softener

Using the following list of parts, choose the one that corresponds to the numbers in Figure 1 and write the name in the appropriate space.

- Soft Water Inlet
- Drain
- Plug Valve
- Bypass Valve
- Feedwater Valve
- Sand
- Brine Inlet Valve
- Fine Clay
- Course Gravel
- Brine Distributing Laterals
- Mixing Valve
- Raw Water Inlet Valve
- Salt
- Brine Injector Valve

1 ______________________________

2 ______________________________

3 ______________________________

4 ______________________________

5 ______________________________

6 ______________________________

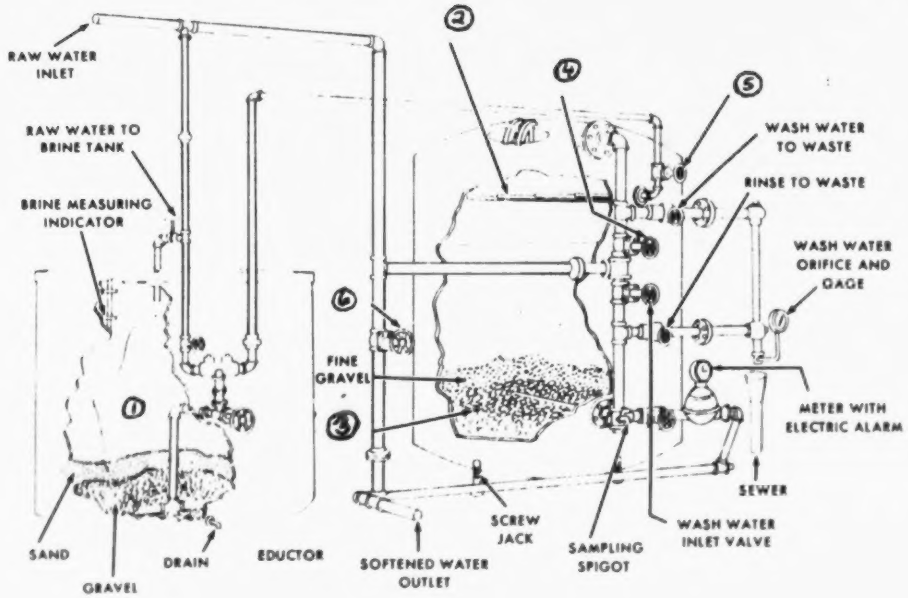

RAW WATER INLET
RAW WATER TO BRINE TANK
BRINE MEASURING INDICATOR
①
②
③
④
⑤
⑥
WASH WATER TO WASTE
RINSE TO WASTE
WASH WATER ORIFICE AND GAGE
FINE GRAVEL
METER WITH ELECTRIC ALARM
SEWER
SAND
GRAVEL
DRAIN
EDUCTOR
SOFTENED WATER OUTLET
SCREW JACK
SAMPLING SPIGOT
WASH WATER INLET VALVE

Figure 1. Zeolite Softener

## Operating Water Softener

Using the following instructions, operate the zeolite water softener trainer.

Instructions. Following the instructions below for operating the water softener trainer. Each item of guidance is important for proper operation and the steps listed should be followed in the order presented.

### SAFETY PRECAUTIONS—

1. This trainer is designed to teach the flow and physical operation of ion-exchangers during different phases of operation. It is recommended that chemicals NOT be used under classroom conditions. If regeneration is desired, use NaCl only.

2. Never allow water pressure in unit to exceed 20 psi.

3. When changing cycles, the hard water inlet valve should be opened last and closed first to prevent excess pressure in system.

### PREOPERATIONAL CHECKS—

NOTE: Check schematic (Figure 2) for location of valves and lines.

1. Close all valves.

2. Check pressure regulator for a system pressure of 15 to 20 psi and adjust if required.

3. If the water level in the ion-exchange tank is more than one inch below the top of the tank, fill and purge air as follows:
   a. Open both backwash valves.
   b. Open hard water inlet valve just enough to allow water to fill tank, but not enough to cause expansion of bed.
   c. When water reaches the distributor in the top of the tank, close the hard water supply and backwash valves.

4. If water level in the brine tank is lower than 3/4 full, fill to desired level as follows:
   a. Open the service valve, drain line, brine outlet valve, and hard water inlet valve.
   b. When the 3/4 full level is reached, close ALL valves, starting with the hard water inlet.

5. If the trainer has been shut down for an extended period of time, place it in fast rinse for a short period of time before placing the trainer in the service.

NOTE: See fast rinse procedures under OPERATING SEQUENCE in this workbook.

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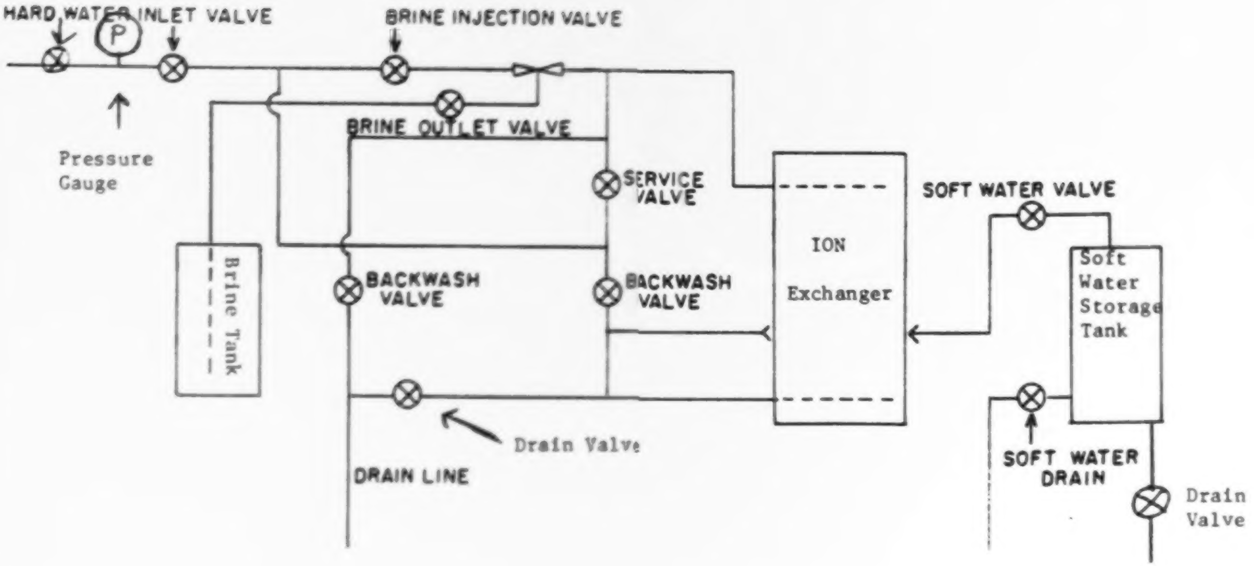
HARD WATER INLET VALVE
P
Pressure Gauge
BRINE INJECTION VALVE
BRINE OUTLET VALVE
SERVICE VALVE
Brine Tank
BACKWASH VALVE
BACKWASH VALVE
ION Exchanger
SOFT WATER VALVE
Soft Water Storage Tank
Drain Valve
DRAIN LINE
SOFT WATER DRAIN
Drain Valve

Figure 2. Schematic of Water Softener Trainer

OPERATING SEQUENCE—

1. Place the unit in service as follows:

   a. Open service valve, soft water valve, and hard water inlet valve.

   b. If soft water tank is over 3/4 full, open soft water drain valve enough to prevent overflow from top of tank.

2. Backwash the bed as follows:

   a. Close all valves, starting with the hard water inlet valve.

   b. Open both backwash valves.

   c. Open the hard water inlet valve slowly until the bed expands approximately 50 percent.

   CAUTION: A too high backwash rate will cause zeolite to wash off to drain. Backwash for one minute.

   d. Stop backwash by closing all valves, starting with the hard water inlet valve.

3. Place unit in the Chemical Injection Phase as follows:

   a. Open brine injection valve, drain line valve, and hard water inlet valve.

   b. Open brine outlet valve. When sufficient chemicals have been drawn into the bed, one to two inches of water, go to step 4.

4. Slow rinse the bed as follows:

   a. Stop chemical injection, step 3b above, by closing the brine outlet valve. This places the unit in slow rinse.

   b. Stop slow rinse by closing brine injection valve. Leave other valves as they are.

5. Fast rinse the bed as follows:

   a. Following step 4b above, open service valve. This places the unit in fast rinse.

   b. To place the unit in service at the end of fast rinse, open soft water valve and close drain line.

POSTOPERATIONAL CHECKS—

1. Check valves and tanks for leaks and cracks.

2. Close all valves except the backwash valve to drain.

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Operating Water Softener (Continued)

1. Brine Test. The brine test is used to determine the brine solution concentration to insure proper regeneration of the sodium zeolite softener.

   a. Fill a cylinder with the brine solution to be tested (brine to be obtained or drawn from the brine tank).

   b. Place the hydrometer in the brine solution and allow to stabilize.

   c. The degree of Baume gravity of the solution is obtained from the stem reading at the point where the surface of the brine touches the stem.

   d. The brine should test 24.6° Baume gravity. This represents 100 percent saturation.

   NOTE: Baume gravity reading times 4 equals approximate percent of percent saturation.

2. Name the three cycles of regenerating the zeolite water softener.

   a. ______________________________

   b. ______________________________

   c. ______________________________

3. What material is used for support of zeolite bed? ______________________________

______________________________

______________________________

## EXERCISE 3

## Water Hardness Tests

A standard soap solution is one of the items needed in order to perform tests for hard water and soft water. Standard soap solutions are placed on the market by manufacturers and chemists; however, each one doesn't have the same lather factor and this must be known before a test can be truly represented. The lather factor on most standard soap solutions will be clearly marked on the label. When the lather factor is not known, the following information can be used as a guide in determining the lather factor of a standard soap solution.

1. Get out the following materials to perform the standard soap solution hardness test:

   1 1/2-pint distilled water
   1 8-oz bottle with stopper
   1 20-ml dropper bottle
   1 0.5-ml dropper
   1 bottle standard soap solution
   1 graduated ml beaker

2. Use following procedures to determine soap later factor:

   a. Pour 30 ml of the distilled water into an 8-ounce bottle.

   b. Using a .5 ml dropper, put one drop of standard soap solution into the bottle containing the distilled water. Stopper the bottle and shake vigorously, then lay the bottle on its side and observe the lather formed.

   c. If the lather formed persists and completely covers the surface of the water for five minutes, one drop will be your lather factor for this particular solution. If not, continue adding drops until you find out how many drops are the lather factor. Once this information is known, record the amount of drops as the lather factor.

3. Using a sample of raw water, determine water hardness.

   a. Pour 30 ml of the sample into an 8-ounce bottle.

   b. Using a .5 ml dropper, add drops of standard soap solution to the sample, a drop at a time. After each drop, shake vigorously. Repeat this step until a lather can be formed that will last five minutes while the bottle is lying on its side.

   c. After a lather has formed that will last five minutes without breaking up, take the total drops used and deduct the amount of drops required by the lather factor. The remaining drops left will equal GPG (grains per gallon) hardness of the sample. To change GPG to ppm (parts per million), multiply GPG by 17.1.

   EXAMPLE: The amount of soap solution used: 11 drops, lather factor 1 drop. Deduct 1 from 11 leaving 10 drops, 10 drops equal to 10 GPG. To change GPG to ppm, multiply 10 by 17.1 which equals 171 – ppm hardnes.

   d. Rinse and clean all test equipment used.

   e. Student test results: ____________________ Soap lather factor

   ____________________ GPG hardness

   ____________________ ppm hardness

Measuring Total Hardness by Volumetric Titration with a Versenate EDTA (Disodium Ethylene Diamine Tetra Acetic Acid) Solution.

1. Get out the following materials to perform the EDTA water hardness test:

| | |
|---|---|
| 1 | Graduated ml beaker |
| 1 | 20-ml dropper bottle with hardness buffer solution |
| 1 | 0.5-ml dropper |
| 1 | Casserole |
| 1 | Hardness indicator powder |
| 1 | Glass stirring rod |
| 1 | Self-leveling burette and bottle with versenate hardness reagent |

2. Using the following procedures, determine water hardness.

   a. Measure 50 ml of water sample in the graduated cylinder and then pour into a casserole.

   b. Add .5 ml of total hardness buffer solution and mix using the rubber-tipped end of the stirring rod.

   c. Add one measure of hardness indicator powder; if powder is not available, use hardness indicator tablet and pulverize using the glass stirring rod.

   d. Fill the burette to the zero mark with versenate hardness reagent, which is done by squeezing the plastic bottle attached to the automatic burettes.

   e. Slowly add the hardness reagent while mixing constantly. The end point is a blue color. Specifically, it is the blue color that is present when the last trace of reddish color has just faded.

   f. Read the number of ml on the burette and determine the ppm of total as CA $Co_3$ by using the formula 20 X ml of titrating solution and record the answer.

   g. Rinse and clean all test equipment used.

   h. Student test results: ________________ ppm hardness

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

# INTERNAL TREATMENT

## OBJECTIVES

Given information, identify principles related to internal boiler water treatment with 80% accuracy.

Given information, select, care for and use precision measuring instruments with instructor assistance.

Following step-by-step procedures, draw water sample and determine chemical concentrations in a steam boiler with instructor assistance.

Given information, explain basic facts pertaining to condensate return treatment with 80% accuracy.

Given step-by-step procedures, test and treat condensate return water with instructor assistance.

## PROCEDURES

1. This workbook is divided into three exercises: Exercise 1--Purpose and Chemical Concentration; Exercise 2--Boiler Water Sampling; and Exercise 3--Boiler Water Analysis.

2. Complete exercises when directed to do so by the instructor.

## EXERCISE 1

## Purpose and Chemical Concentration

Correctly fill in the blanks in the chart by placing the appropriate chemical, purpose, concentration or X-factor.

| CHEMICAL | PURPOSE | CONCENTRATION | X-FACTOR |
|---|---|---|---|
| | | 3 $\underline{M}$ | |
| | Alkalinity — pH control<br>(Also precipitates magnesium) | | |
| Amines Treatment | | | ╳ |
| Phosphate | | | |
| | Determines amount and frequency of blowdown | | |
| | | 20-40 ppm | |

## EXERCISE 2

### Boiler Water Sampling

1. All samples must be drawn immediately before ________________________________________

   and before ________________________ are added.

2. Blow down the sampling point several times and adjust the sampling line to reach to the bottom of the bottle; run a sufficient amount of boiler water into the bottle to rinse the bottle and the stopper. Discard this rinse water and fill the bottle with boiler water. Run the sample long enough to overflow the top to expel all air from the bottle and for the removal of sample previously exposed to the air in the bottle.

# EXERCISE 3

## Boiler Water Analysis

1. Sodium Sulfite Test

The sodium sulfite test is performed to measure sodium sulfite content in the boiler water when this type of treatment is used. Sodium sulfite acts with oxygen very rapidly in the hot boiler water forming sodium sulphate. Sodium sulfite treatment is used to supplement mechanical methods and tannin as removal agents. When the remaining dissolved oxygen content remains high and sodium sulfite treatment is instituted, a concentration between 20 and 40 ppm is usually considered satisfactory.

MATERIALS----

One graduated cylinder

One stopper for graduated cylinder, No. 5

One dropper, 7-inch, marked IOIO

One stirring rod

One dropping bottle, 30 ml ----- with dropper marked at 1/2 ml for starch indicator.

One dropping bottle, 30 ml ---- with dropper marked at 1/2 ml for hydrochloric acid 3N.

One pint amber bottle of standard potassium-iodate-iodide reagent.

NOTE: STARCH indicator must be mixed fresh locally. Put on rubber apron befor performing any tests.

PREPARING THE STARCH----

This indicator must be prepared right at the plant. Measure out a level 1/4 teaspoonful of potato or arrowroot starch and transfer to the 50 ml beaker. Add a few ml of distilled water and stir the starch into a thin paste using the glass end of the stirring rod provided. Put 50 ml of distilled water into the 150 ml beaker. It is convenient for this step to have the 150 ml beaker marked at the point where it holds 50 ml, or one of the marked test tubes can be used by filling it to the fourth marked above the long mark with distilled water. Bring the water in the 150 ml beaker to a boil by any convenient method. Remove the source of heat from the boiling water and immediately pour the starch paste into the boiling water while stirring the solution. Then put a crystal of thymol into the starch solution. Stir. After the solution has cooled, discard, by pouring off, any scum on the surface and transfer 20 ml to the indicator dropping bottle provided. The starch solution loses its sensitivity as an indicator after a time. Addition of the thymol to the starch preserves it so that it can be used in this test for about two weeks. The starch should be dated when prepared.

TESTING PROCEDURE____

Transfer one ml of hydrochloric acid 3N to a clean graduated cylinder by measuring out two 1/2-ml portions with the dropper supplied with the hydrochloric acid 3N dropper bottle.

Add 1/2 ml of starch solution with the dropper supplied with the starch indicator dropper bottle.

Without disturbing any sludge that has settled out, in the sampling bottle, pour enough sample over into the graduated cylinder to bring the level up to the 25 ml mark. Stir the mixture in with the plunger end of the stirring rod.

Fill the 7-inch dropper with standard potassium iodate iodide reagent from the stock bottle by sucking it up with the rubber bulb. The dropper must be reserved for this test only and maintained in a clean condition to prevent possible contamination.

Add the reagent to the mixture in the graduated cylinder one drop at a time, counting the number of drops and stirring after each drop is added until a permanent blue is obtained which is not removed by stirring. Stop the addition of the reagent as soon as the permanent blue is obtained.

Last drop of standard potassium iodide reagent used (EXCEPT THE LAST ONE) times 5 would be the concentration of sodium sulfite in the boiler water.

STUDENT RESULTS OF TEST -----

____________________ppm sodium sulfite.

2. Causticity Test

The causticity test is used to determine the amount of free causticity of hydroxide (HO) in the boiler water. A causticity concentration maintained between 20 and 200 ppm by using caustic soda will neutralize acid materials in the water. In addition to the neutralizing action, the free hydroxide combines with magnesium salts to form magnesium hydroxide, a soft finely divided sludge which can be easily removed from the boiler by blowdown. Alkaline water will usually prevent corrosion. Our discussion will be limited to the precipitation method of testing.

MATERIALS -----

Three graduated cylinders marked in ml.

Two rubber stopers, solid No. 5.

One 9-inch stirring rod.

Two 250-ml plastic reagent dispensing bottles containing causticity reagent No. 1 and causticity reagent No. 2 solution.

One 1-ounce indicator dropping bottle for phenolphthalein.

One test tube rack.

TESTING PROCEDURE ----

When testing boiler water which is appreciably colored by organic material such as tannin, it is desirable to start with a warm sample, say about 160°.

Without disturbing any settled sludge in the container, fill two graduated cylinders exactly to the 25 ml. mark with some of the original boiler water.

Shake thoroughly causticity reagent No. 1 (Barium Chloride solution).

Add enough to each of the two graduated cylinders to bring the levels exactly up to the 30 ml. mark.

At this point a precipitate generally forms in the mixture in two tubes.

Stir the mixture in the cylinders with the stirring rod.

NOTE: Do not strike the end of the stirring rod against the bottom of the cylinders.

Stopper them and let them stand until any precipitate formed has settled to the bottom of the tubes.

This precipitate carries down with it much of the tannin or other colored materials in the mixture.

NOTE: The settling may take from two to fifteen minutes. A warm sample will usually shorten the required settling time.

Without disturbing any precipitate which has settled to the bottom of the two cylinders pour enough of the solution from the top of each of the cylinders into the third cylinder to bring the level in the third cylinder up to the 30 ml. mark.

If the solution in the cylinder is not pink, add two drops of phenolphthalein indicator; if the solution does not turn pink when the phenolphthalein indicator is added, there is no causticity in the sample. The test is finished.

If the solution in the cylinder is pink, it shows the presence of causticity in the boiler water. Continue the testing procedure.

With the 8-inch dropper, add just enough causticity reagent No. 2 (1/30 hydrochloric acid) to the solution drop by drop. Stir the solution with the stirring rod to neutralize the causticity in the solution; the pink color will disappear. Stop the addition of the reagent as soon as the pink color just fades out.

The amount of reagent used is shown by the number of ml. above the 30 ml. mark.

The number of milliliters of causticity reagent No. 2 used multiplied by 23 gives the causticity in parts per million of hydroxide (HO) in the boiler water sample.

Thus, if 3 ml of causticity reagent No. 2 were used, there are 3 x 23 or 69 ppm of hydroxide in the boiler water sample.

STUDENT RESULTS OF TEST ----

Number of milliliters causticity reagent No. 2 ______________________________

Multiplied by 23 = ________________ ppm causticity.

Steam boiler pH __________________ using litmus paper or pH meter and directions from your instructor.

3. Phosphate Test

The phosphate test is used to determine the amount of soluble phosphate in the boiler water. Maintaining a phosphate level between 30 ppm and 60 ppm by addition of sodium metaphosphate will result in the sodium metaphosphate combining with some of the free hydroxide (formed by the addition of caustic soda) forming trisodium phosphate. The trisodium phosphate combines with calcium salts, in the water, to form tricalcium phosphate, a soft, nonadhering, finely divided sludge which can be easily removed from the boiler by blowdown. There are several methods of determining the phosphate level; however, for our studies we will limit the discussion to the color-metric method.

MATERIALS------

One phosphate color comparator block.

One phosphate comparator combination mixing tube marked 5, 15, 17.5 ml and stopper.

One filter funnel, 65 mm diameter.

One package filter paper, 11 cm.

One bottle, 20 ml.

One dropper, 1/2 ml.

One measuring spoon, 1/4 teaspoon size.

One plain test tube 22 x 175 mm about 50-ml capacity and rubber stopper.

One plastic bottle of "Comparator Molybdate reagent".

Two ounces Concentrated Stannous Chloride reagent.

Decolorizing carbon.

Distilled water.

TESTING PROCEDURE------

Without distrubing the settled sludge in the sample, transfer sufficient amount of the sample to fill the plain test tube about halfway.

Add 1/4 teaspoon of decolorizing carbon, place stopper in the tube and shake vigorously for about a minute.

Fold a filter paper and place in the funnel. Place the funnel in the comparator combination mixing tube.

Filter enough sample to bring it up to the first mark of 5 ml. Discard this filtrate. Filter another sample.

Add comparator molybdate reagent to bring the level just up to the second mark (15 ml).

Add fresh dilute stannous chloride up to the third mark (17.5 ml). This solution should be prepared the day it is to be used. Put .5 ml concentrated stannous chloride in 20-ml bottle. Fill bottle to shoulder with distilled water.

Stopper the mixing tube. Invert it several times. If there is any phosphate in the sample, the solution in the mixing tube turns blue.

Place the tube in the opening provided in the comparator block. If the sample color comes between the two standard ranges of 30 to 60 ppm, the boiler water is satisfactory.

STUDENT RESULTS OF TEST------

______________________________ ppm phosphate.

## 4. Tannin Test

The tannin test is made to determine the approximate concentration of tannin in the boiler water. Tannin acts as an oxygen absorber and due to its colloidal action it can make the sludge form as very finely divided particles, thus being more fluid, so that it is carried by the circulating boiler water and is removed more readily by blowdown. The limit for tannin content of boiler water is a medium-brown color as shown by the middle standard of the tannin color comparator.

### MATERIALS-----

One improved tannin color comparator.

One square tube, 13 mm viewing depth.

One plain test tube, 22 mm X 175 mm.

One package filter paper, 11 mm.

### TESTING PROCEDURE------

Without disturbing any settled sludge in the sample, fill the plain test tube to within an inch or two of the top with boiler water being tested. The boiler water should preferably be cooled slightly.

Fold a filter paper and place it in the funnel without wetting it down. Place funnel in a square test tube in the comparator and filter the sample from the plain test tube until it is nearly filled.

Remove the square test tube and note the appearance of the filtered boiler water; it should be free of suspended solids or sludge; refilter it, using the same funnel and filter paper until it does come out free of solids.

Set the square test tube containing the filtered sample back in the middle slot of the comparator and compare the color of the sample with the five color standards viewing against a source of very bright daylight.

The color standard which most closely matches the color of the filtered sample gives the tannin color of the boiler water.

For ordinary boiler water conditions, the tannin dosage is usually satisfactory if it maintains a medium tannin color in the boiler water; that is, the filtered boiler water matches the No. 3 tannin color standard.

NOTE: The result of the TANNIN TEST is used in the dissolved solids test.

NOTE: Where the boiler water causticity is high or where severe boiler corrosion difficulties are encountered, the tanning dosage is sometimes adjusted to maintain a dark or No. 4 color.

STUDENT RESULTS OF TEST-----

______________________________tannin.

## 5. Dissolved Solids Test

The dissolved solids test is used to determine the concentration of soluble salts in boiler water and as a control to determine the amount and frequency of blowdown. The specified limits for boiler water dissolved-solid content are between 1000 and 4000 ppm. Testing for dissolved solids will be limited to the electrical conductivity method in this course.

MATERIALS-----

One model RD-P4 Solu-Bridge conductivity method or equal.

One model CEL-S2 polystyrene dip-type conductivity cell, constant 2.0.

One thermometer, armored, 0-200° F.

One pint conductivity-neutralizing solution.

Two 200 mm X 38 mm test tubes with stoppers.

One 1-ounce indicator dropping bottle with 1/2 ml dropper.

TESTING PROCEDURE-----

Without disturbing settled sludge in sample container, pour 60 ml of it into the test tube.

Add two droppersful (filled to the mark) of conductivity - neutralizing solution. Stopper and invert several times to mix.

Connect the terminals of the dip cell to the appropriate terminals of the conductivity meter.

Fill a clean 200 mm X 38 mm test tube about halfway with distilled water and clean the cell by moving it up and down several times in the distilled water. Remove the cell and shake it to remove excess distilled water.

Immerse the cell in the sample being tested to a point where the level of the solution is at least 1/2-inch above the vent holes. Move the cell up and down several times, making sure that the vent holds remain below the liquid level. This action will release any air bubbles adhering to the inner cell wall.

Plug the instrument cord into a 105- to 120-volt, 50-60 cycle ac outlet and turn on the control switch.

After the thermometer reading has stabilized, set the instrument temperature adjustment knob to correspond with the thermometer reading. Remove thermometer and set the cell as near center in the test tube as possible.

After the instrument has warmed up, rotate the control dial of the instrument until the dark segment of the electron tube reaches its widest pattern and a sharp shadow is obtained.

To calculate the results in parts per million (ppm), multiply the reading obtained from the control dial scale by one of the following conversion factors:

| Tannin Number is: | Factor Instrument 64°F - 18°C | Factor Instrument 77°F - 25°C |
|---|---|---|
| 0 | .8 | .7 |
| 1 | .9 | .8 |
| 2 or 3 | 1.0 | .9 |
| 4 or 5 | 1.1 | 1.0 |

EXAMPLE: If the sample has a tannin number of 1, using 64°F - 18°C instrument and a specific conductance reading of 3100, the concentration of the sample is 3100 X .9 or 2800 ppm.

STUDENT RESULTS OF TEST——

________________________ ppm dissolved solids.

6. Condensate pH Test

Condensate return is tested for pH to determine if condensate alkalinity has decreased to the point where return line corrosion will occur. This type of corrosion is common in installations having extensive return systems. When steam is formed, the bicarbonates in the feedwater go to carbonates in the hot water and form hydroxides. Carbon dioxide is formed in both actions and leaves with the boiler steam. When the carbon dioxide condenses with the steam, it forms carbonic acid giving a pH sometimes as low as about 5. By the use of a group of the compounds called "amines", the pH of the condensate can be maintained just on the alkaline side, say 7.0 to 7.5, and corrosion in the return lines can be reduced.

MATERIALS——

One 4-ounce brown bottle of condensate pH indicator.

One ounce indicator bottle with dropper marked at .5 ml.

One 10-ml beaker marked at 50 ml.

One stirring rod, glass 9-inch.

TAKING THE SAMPLE OF CONDENSATE——

Take the sample near a point in the return piping where the condensation takes place, such as right after a trap, or preferably at a point where return line corrosion is known to be occurring. For the sample to be representative of water flowing in the return lines, it should not be taken from a collecting tank. Cooling the condensate is not necessary. However, collect it slowly to reduce flashing.

TESTING PROCEDURE——

Measure out 50 ml of sample; place in 100 ml beaker.

Fill the dropper to the .5 ml mark with a pH indicator; transfer to the sample in the beaker and stir with glass rod.

If the solution in the beaker is colored green, the condensate is acid and the dosage of chemical being used to raise the pH of the condensate should be increased.

If the solution is colored a light pink, the pH is neutral or slightly alkaline and the chemical dosage is satisfactory.

If the solution is colored red or purple, the pH is higher than necessary and the chemical treatment for the condensate should be reduced.

STUDENT RESULTS OF TEST——

________________________ pH condensate.

| Recommended Residual | Chemical | Student's Results |
|---|---|---|
| 20-40 ppm | Sodium Sulfite | |
| 20-200 ppm | Sodium Hydroxide | |
| 30-60 ppm | Phosphate | |
| 3$^{\underline{m}}$ | Tannin | |
| 1000-4000 ppm | Dissolved Solids | |
| 7.0 —— 7.5 pH | Amines | |

Boiler pH ______________ (HTHW, STEAM)

## EXERCISE 4

### Condensate Return Treatment

Complete questions in spaces provided.

1. What dissolved impurity causes condensate return line corrosion?

2. Carbon dioxide and condensate water mixing together forms what?

3. Condensate return line corrosion results in?

4. What is used to control condensate return line corrosion?

5. What types of amines are used by the Air Force?

6. What is the range for condensate return water?

7. The use of neutralizing amines will result in the pH of condensate water increasing or decreasing?

8. What is used to determine if condensate treatment is needed?

9. Where is the corrosion test nipple installed?

10. Where is the condensate corrosion test nipple sent to?

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

WB J3ABR54532 001-VIII-4

# LOGS AND CHEMICAL FEEDING

## OBJECTIVES

Following step-by-step procedures, maintain water treatment log with 80% accuracy.

Given information and equipment, prepare boiler water sample for shipment with instructor assistance.

Given information and chemical formulas, compute chemical requirements with instructor assistance.

Given information, determine step-by-step procedures for installation and servicing of chemical feeding equipment with 80% accuracy.

Using step-by-step procedures, service chemical storage area with instructor assistance.

Using step-by-step procedures, perform chemical feeding with instructor assistance.

## PROCEDURE

### EXERCISE 1

### Water Treatment Logs

Complete the following statements.

1. The title of AF Form 1459 is ______________________________

______________________________________________________________

2. Instructions for completing AF Form 1459 are found ______________

______________________________________________________________

3. Complete each of the following control procedures for AF Form 1459.

   a. Frequency: ______________________________________________

   ______________________________________________________________

   b. Preparation: ____________________________________________

   ______________________________________________________________

   c. Distribution: ___________________________________________

   ______________________________________________________________

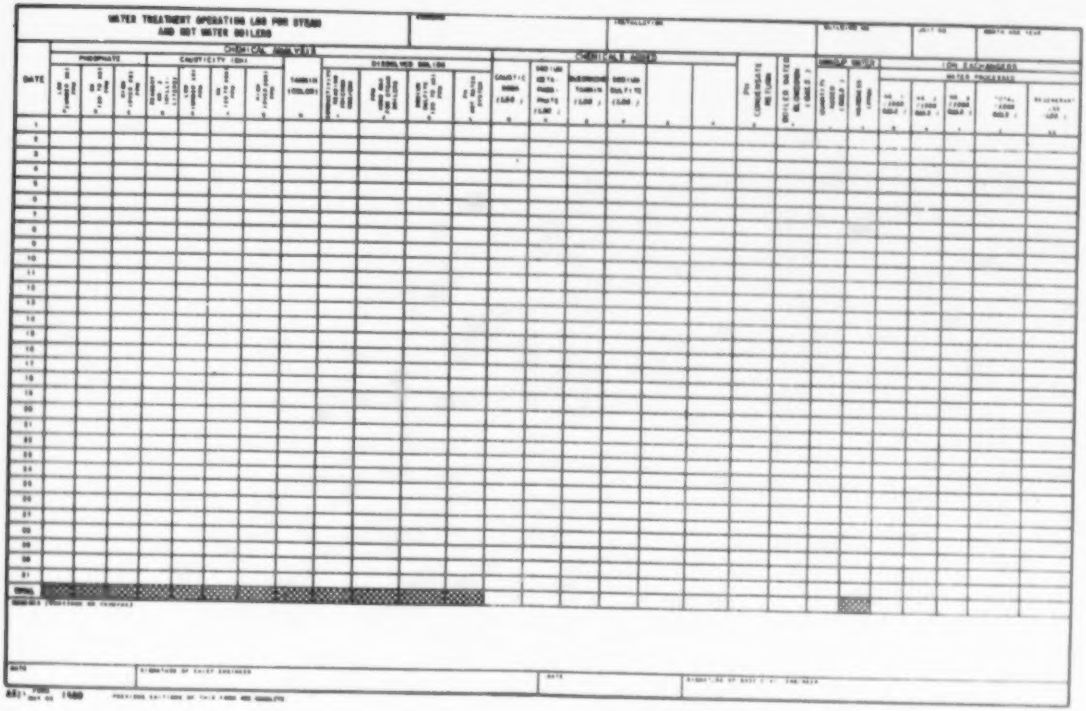
   d. Due Date: _______________________________________________

   ______________________________________________________________

## EXERCISE 2

### Annotation of AF Form 1459

NOTE: Using test results previously attained, complete AF Form 1459 in accordance with instructions found on reverse of form (see Figures 3 and 4).



WATER TREATMENT OPERATION LOG FOR STEAM AND HOT WATER BOILERS

CHEMICAL ANALYSIS

PHOSPHATE

CAUSTICITY (OH)

TANNIN (COLOR)

DISSOLVED SOLIDS

CHEMICALS ADDED

CAUSTIC SODA (LBS.)

SODIUM META-PHOSPHATE (LBS.)

QUEBRACHO TANNIN (LBS.)

SODIUM SULFITE (LBS.)

CONDENSATE RETURN

BOILER WATER BLOWDOWN

MAKEUP WATER

ION EXCHANGERS

WATER PROCESSED

DATE

Figure 3. AF Form 1459

## INSTRUCTIONS

AF Form 1459 is to be used for recording water treatment data for all steam and hot water boilers that need chemical treatment. It will be prepared in duplicate by the engineer in charge at the central heating plant. The log will be posted daily and forwarded at the end of the month to the base civil engineer for review and approval. After approval the base civil engineer will forward the second or carbon copy to the major command civil engineer not later than the 20th of the following month. No logs will be forwarded to Headquarters USAF.

Column A thru C. For steam boilers only. Enter in the appropriate column the parts per million (p p m) of phosphate found by the colorimetric method.

Column D. Enter the number of milliliters (ml.) of causticity Reagent No. 2 required to destroy the pink color.

Column E thru G. Required for steam boilers. Multiply the value entered in Column D by 23 to obtain the result in parts per million OH and enter in appropriate column.

Column H. For steam boilers only. Enter the number for the proper color designation for the filtered sample of boiler water as determined with the color standards. Colors are (1) very light, (2) light, (3) medium, (4) dark, (5) very dark.

Column I. Enter the reading obtained from the conductivity meter. (See Bureau of Mines Form BMS-21).

Column J. Enter the dissolved solids in ppm as calculated by multiplying the conductivity reading (column I) by the proper conversion factors.)

Column K. Enter the ppm sulfite content as determined by test for sodium sulfite (see Bureau of Mines Form BMS-7). High temperature water heating systems require 20-40 ppm sodium sulfite. This chemical is not to be used in steam boilers except on approval by major command.

Column L. For high temperature water systems, i.e., 300°F water and higher. Enter the pH of the sample tested. Required range is 9.3 to 9.9.

Column M thru R. Enter the total number of pounds of each chemical added to the boiler or hot water generator during the day. Use the blank columns for chemicals added other than those listed in column M thru P, such as filming and neutralizing amines.

Column S. Enter the pH of the condensate return water. If a pH meter is not available, use the Bureau of Mines test kit for condensate pH and enter color reading.

Column T. Determine the total number of gallons of blowdown water and enter the amount in this column. Do not blowdown high temperature water systems.

Column U. Enter the total gallons of makeup water.

Column V. Enter the hardness in ppm of the makeup water.

Column W thru AA. These columns are used for central heating plants that have ion exchangers in conjunction with their operation either for sole or partial use of the heating plant. Enter in columns W, X, and Y, the quantity of water processed daily in each ion exchanger. Enter in column Z the total quantity in gallons of water processed to the heating plant through all exchangers. Enter in column AA the quantity and type of chemical (salt, acid or alkali), used to regenerate the ion exchangers.

Remarks. The remarks space may be used to indicate any unusual conditions or to report special data. Use the reverse of form if additional space is necessary.

Figure 4. Reverse of AF Form 1459

## EXERCISE 3

### Sample Submission Requirement

### PART I

Given information and equipment, prepare boiler water sample for shipment, with instructor assistance.

PROCEDURES

1. Blowdown sample lines
2. Rinse equipment
3. Discard rinsewater
4. Draw sample slowly
5. Place sample line to bottom of bottle
6. Overflow bottle
7. Stopper bottle
8. Label bottle
9. Place labeled sample into mailing container for shipment to the AF Contract Lab.

PLEASE ENTER THE FOLLOWING INFORMATION

POST OR INSTITUTION ____________________

BUILDING NAME AND NUMBER ____________________

DATE ____________________

BOILER NUMBER ____________________

## EXERCISE 3

## Sample Submission Requirements

## PART II

Use SG J3ABR45432 001-VIII-4 to complete the following statements:

1. Complete the following schedule for submitting samples to the AF contract laboratory. List the frequency on line for each type.

   a. High Pressure - 100 hp or higher.

   ______________________________________________

   b. High Pressure - Under 100 hp.

   ______________________________________________

   c. Low Pressure - 100 hp or higher.

   ______________________________________________

   d. Low Pressure - Under 100 hp.

   ______________________________________________

   e. High-Temperature Water Plants - 350°F and above.

2. Samples of water from government-operated boiler plants must be sent to the AF Contract Lab to be analyzed as directed by:

   ______________________________________________

3. How are sample containers acquired?

   ______________________________________________

   ______________________________________________

4. The ______________________ bottle is used for low-pressure boiler water samples.

5. The ______________________ bottle is used for high-pressure boiler water samples.

6. The reasons for submitting boiler water samples to the AF Contract Laboratory are:

   a. ______________________________________________

   ______________________________________________

   b. ______________________________________________

   ______________________________________________

Major changes in water treatment will be made only when directed by:

______________________________________________

______________________________________________

## EXERCISE 4

### Procedures for Computing Chemical Dosages

Use the following formulas and given information to determine the proper dosage o each chemical.

1. SODIUM SULFITE

**Formula:**

$$\frac{\text{pounds of feedwater X ppm } O_2 \text{ in feedwater x 8.8}}{1{,}000{,}000} + \frac{\text{pounds of feedwater X \% of blowdown x .3}}{1{,}000{,}000}$$

Boiler used 720,000 pounds of feedwater with .5 ppm $O_2$. There was 3% blowdown.

Answer ______________ pounds

2. CAUSTIC SODA

**Formula:** 3/4 pounds per 3000 pounds of steam/hr OR

3/4 pounds for every 100 boiler horsepower

Boiler produces 30,000 pounds of steam/hr.

Answer ______________ pounds

3. PHOSPHATE

**Formula:** Pound phos = $\frac{\text{pounds make-up X hardness in ppm X 1.8}}{1{,}000{,}000}$

Boiler uses 35,000 pounds of make-up with 8 ppm hardness

Answer______________pounds

4. TANNIN

**Formula:** 1/2 pound per day for every 3,000 pounds steam/hr

Boiler produces 30,000 pounds of steam/hr.

Answer ______________ pounds

5. AMINES

**Formula:** $\frac{\text{pounds make-up per day X } CO_2 \text{ in make-up in PPM X 3.3}}{1{,}000{,}000}$

Boiler uses 3,500 gallons make-up per day
$CO_2$ in make-up is 20 ppm
NOTE! You must convert gallons to pounds

Answer ______________ pounds of 60% Cyclohexylamine

## EXERCISE 5

### Chemical Handling and Feeding

1. When mixing chemicals for internal boiler water treatment, what protective items must you have on?

   a. ______________________________ for eye protection.

   b. ______________________________ for clothing protection.

   c. ______________________________ for protection of hands.

2. There are a few general rules that apply to the mixing of the acids and strong bases that are commonly used in boiler water treatment; they are as follows:

   a. ______________________________

   b. ______________________________

   c. ______________________________

3. How high can chemicals be stacked?

   ______________________________

4. Chemicals should be stacked on ______________ in a ______________,

   ______________ place.

5. Name three types of chemical feed systems.

   a. ______________________________

   b. ______________________________

   c. ______________________________

## EXERCISE 6

## Chemical Feeding

PROCEDURES

1. Put on protective equipment.
2. Fill a bucket halfway with cold water.
3. One student will stir water while team member adds predetermined amount of chemicals.

   NOTE: Make sure all chemicals are dissolved in water.

*4. Isolate chemical feed tank, open drain valve and vent valve.

5. Close drain valve and open fill valve.
6. Add mixed chemicals slowly to tank.

   NOTE: Fill tank completely with water.

7. Close fill valve and vent valve.

*8. Open feedwater line valves to tank.

9. Line up feedwater system to boiler and turn on pump.

   NOTE: Use bypass and instructor will determine when chemicals are in boiler.

10. Secure pump and feedwater line valves, drain tank.

3770 Technical Training Group
(Civil Engineering Training)
Sheppard Air Force Base, Texas

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# EXTERNAL CORROSION

## OBJECTIVES

Given information, identify basic facts about external corrosion with 70% accuracy.

Given information, make visual inspection and identify external corrosion with instructor assistance.

## PROCEDURE

### EXERCISE 1

Complete the following.

1. List the types of corrosion:

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

g. ______________________________

h. ______________________________

i. ______________________________

j. ______________________________

k. ______________________________

l. ______________________________

m. ______________________________

n. ______________________________

o. ______________________________

p. ______________________________

q. ______________________________

r. ______________________________

2. What is corrosion?

______________________________________________________________

______________________________________________________________

______________________________________________________________

3. What items are necesasry for a galvanic cell?

NOTE: Use Figure 5.

4. Draw arrows showing the current flow.

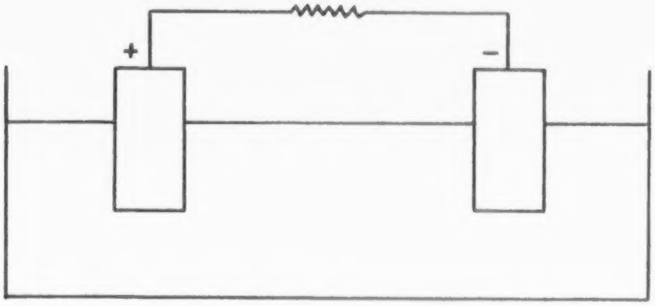

Figure 5

5. What is the de-zincification process?

6. (CHOOSE ONE) Mill scale formation of a pipe will tend to be the (anode/cathode) of a pipe.

7. What is meant by "dissimilar metals"?

## EXERCISE 2

Complete the following.

1. List the methods of combating corrosion.

a. ______________________________________________

b. ______________________________________________

c. ______________________________________________

d. ______________________________________________

2. What are some of the materials used in coating metals?

______________________________________________

______________________________________________

______________________________________________

3. What are the two types of cathodic protection systems used?

a. ______________________________________________

b. ______________________________________________

## EXERCISE 3

## Inspection For Corrosion

PROCEDURE

1. Proceed to the lab area.

2. Inspect for external corrosion on feedwater system or as directed by the instructor.

3. List any corrosion found.

Type: ____________________________________________

____________________________________________

____________________________________________

Location: ____________________________________________

____________________________________________

____________________________________________